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LAKE AND POND MANAGEMENT Coursebook

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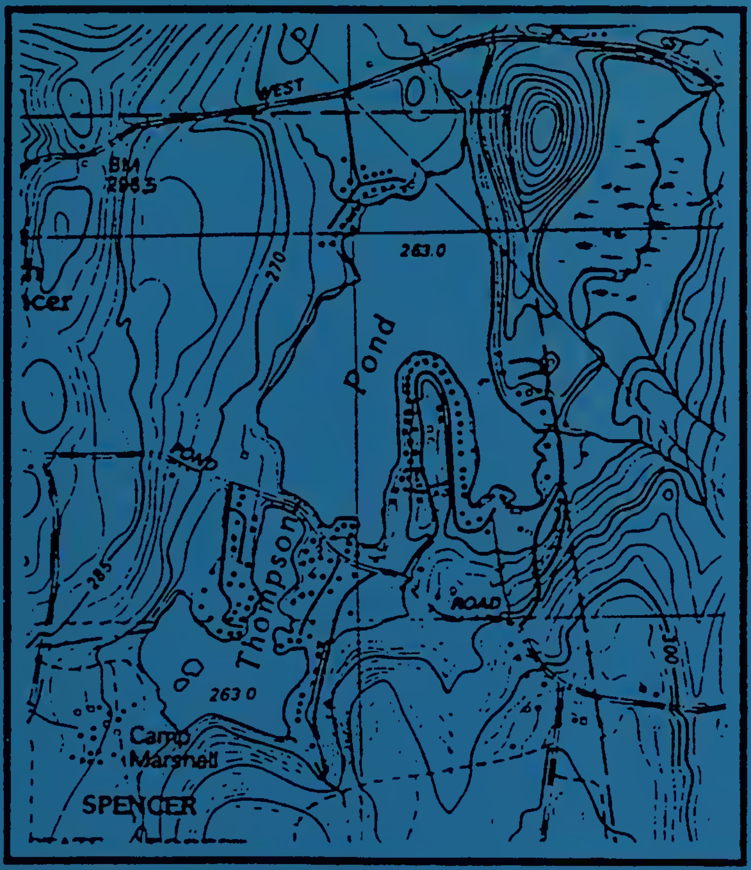
Massachusetts Department of Environmental Management



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A Comprehensive Short Course in
Strategies to Preserve and Restore Lakes

1996 New England Lake Conference Edition

This special edition was made possible through a generous contribution from **Raytheon Company** in support of watershed awareness and the Massachusetts Watershed Initiative

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Lycott Environmental Research, Inc.

INTRODUCTION TO THIS SPECIAL PRINTING FOR THE 1996 NEW ENGLAND LAKE CONFERENCE

This special edition was made possible through a generous contribution from Raytheon Company in support of watershed awareness and the Massachusetts Watershed Initiative.

What is the Massachusetts Watershed Initiative:

The Watershed Initiative has been working over the past few years to promote watershed awareness and create the community based approach to environmental planning, protection and regulation using the watershed as the management unit.

The overall goal of the Initiative is to protect and improve water quality in Massachusetts' 27 major river basins and in the coastal basin. The effort is collaborative, bringing together and representing economic, environmental, and political interests to achieve common goals and to provide an integrated management and technical framework to address the problems of each river basin.

The Initiative bases its direction jointly on the priorities, and interests of local groups and citizens and on the regulatory requirements established to protect the resources of each basin. Citizens, businesses, non-profits, and state and federal agencies are working in partnership to address mutual concerns; deal with a whole set of complex issues; and allocate their technical, organizational and financial resources to gain the most environmental benefits.

To find out more. contact: **Massachusetts Watershed Initiative Steering Committee,**
EOEA, 100 Cambridge Street, Boston, MA 02202.
(617)727-9800

The Watershed Initiative is designed to:

1 Enable watershed associations, community groups (such as lake and pond associations), businesses, local governments and other entities in each basin to understand and address local water resource management needs through public education and outreach;

2 Support community based decision making that will improve, protect, and enhance the water resources of the river basin by coordinating efforts among state and federal agencies, regional planning agencies, and other public entities, providing technical expertise, establishing forums for these actions and responding to local concerns;

3 Develop realistic measurable goals and implement a plan of action that can support and sustain the environmental and economic values of concern to watershed communities.

This Coursebook, Field Manual, and conference are vital educational tools and forums to advance watershed management and planning as key elements to intelligent lake and pond management.

Lake and Pond leaders throughout New England have been pioneers in the "watershed approach" to land- and water-use planning for decades. In many cases, these leaders have felt as though their efforts amounted only to "crying in the wilderness." With the creation of the Watershed Initiative, it is clear that watershed management has now become a broad public concern. Raytheon's partnership and generous contribution to that effort is deeply welcomed and appreciated.

Members of NEC-NALMS and COLAP

INTRODUCTION

WELCOME TO THE LAKE AND POND EDUCATIONAL PROGRAM

The following lakes assessment and management curriculum is grounded in the sciences, yet is focused on the practical problems facing DEM staff. It is our pledge to cover, in as much detail as possible, the topics outlined in the enclosed course agenda. Please feel free to ask questions and share your experiences and concerns with us.

This workbook consists of materials relevant to lake and pond assessment and management. The workbook includes extended lecture outlines--intended for note-taking--written text which covers the lecture subject matter, worksheets to allow in-class calculations, and sources of further information.

A field manual has also been prepared for this course and is available from the DEM. This field manual illustrates the methodologies which can be used for ongoing lakes management and assessment.

Thank you for your participation!

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LAKE AND POND EDUCATIONAL PROGRAM

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ACKNOWLEDGEMENTS

This coursebook was prepared under funding provided by Massachusetts Department of Environmental Management (DEM). It is intended as a training manual for DEM staff members and lake managers.

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DESCRIPTION OF LAKE FUNCTIONS

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SECTION 1: DESCRIPTION OF LAKE FUNCTIONS

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2. Importance to lake function

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1. Sources/Sinks
2. Importance to lake function
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1. Typical forms
2. Importance to lake function

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Description Of Lake Functions

WHAT IS A LAKE OR POND?

Lake and ponds constitute one of Nature's most diverse habitats, and one of man's most desired recreational areas. As such, an informed understanding of their form and function is critical to their proper management. The following information is intended as a primer in the fundamentals of lake science.

Ponds vs. Lakes

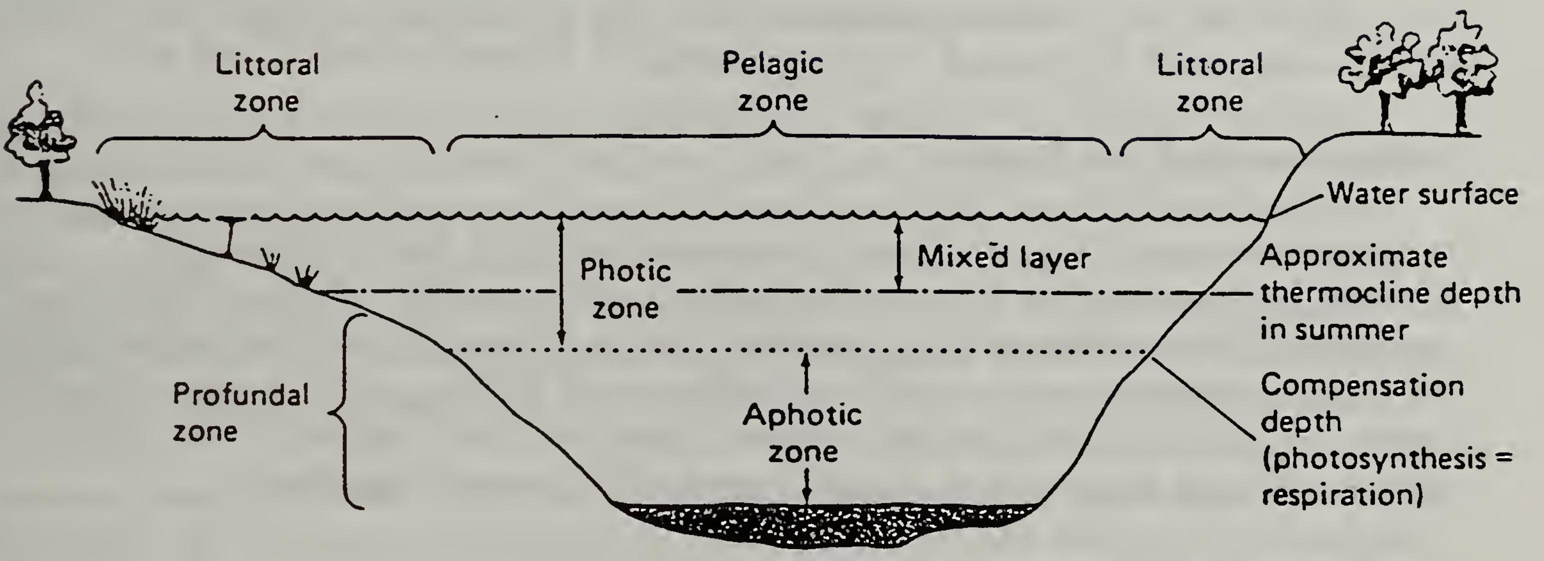
For our class we will consider a pond or lake to be a body of fresh water that has standing water all year round, a flora and fauna adapted to this permanent pool of water, and an average exchange of water in the order of weeks or greater. This would eliminate streams, rivers, and other swiftly flowing waters. In these situations the rapid movement of water does not allow for significant biochemical exchanges or differentiation (zonation) to develop within the water column. Of course it is possible for a large reservoir to behave like a river some portions of the year, and like a lake during others, depending on the volume of flow through the system.

Similarly, the distinction between pond and lakes is at best a fuzzy one. The Massachusetts Wetlands Protection Regulations (310 CMR 10.00) define ponds as waterbodies greater than 10,000 square feet and lakes greater than 10 acres. It has also been suggested that lakes are mixed primarily by wind action and ponds by convective internal heating.

For our purposes a pond is defined as a shallow body of water, with light reaching the bottom, no sharp difference in temperature between top and bottom waters, and rooted aquatic plants throughout. In contrast, a lake is defined as a deep body of water, with unlit bottom waters, a seasonally distinct difference between top and bottom waters and rooted aquatic plants limited to the margins.

We have more precise limnological terms (limnology is the study of inland waters, analogous to oceanography for marine waters) for the various zones alluded to above. These are illustrated in Figure 1.1. The littoral zone is the shoreline area extending out into the lake to the limit of the rooted aquatic plants. The open-water portion of the lake is called the pelagic zone. The

FIGURE 1.1
IDENTIFICATION AND LOCATIONS OF IMPORTANT ZONES IN LAKES.



SOURCE: Goldman and Horne 1983.

bottom of the lake beyond the margin of the littoral is referred to as the profundal zone.

A second designation is based on the penetration of light into the lake. The upper layer which is well-lit is termed the photic zone. The photic zone extends from the lake surface down to a depth where the light is about 1% of the surface irradiance level. The waters beneath constitute the aphotic zone where there is insufficient light for plants to photosynthesize.

Lastly, there is a seasonal division of upper and lower waters into a mixed layer that can exchange with the atmosphere and a bottom layer than does not mix, separated by a thermal discontinuity, the thermocline. This layering or stratification will be treated in greater detail in a later section of this text.

Massachusetts Great Ponds

In Massachusetts there are Great Ponds (no kidding), with ordinances concerning these bodies of water going back as far as 1641. A Great Pond is a recognized body of water greater than 10 acres in area. This designation grants ownership rights (more-or-less) to the State and allows public access. These rights originated during colonial times when you could legally cross fields to hunt or fish, as long as you didn't trample the owner's cornfield.

Vernal Pools

Also in Massachusetts, there has been the recent legal recognition of vernal pools as unique habitats protected under the Wetland Protection Act. These are temporary aquatic water bodies that are habitat or spawning areas for selected amphibian and insect species. Under the Act, vernal pools are recognized by the following characteristics - having water in the basin for two continuous months, lacking fish and/or drying out during the year, and maintaining typical vernal pool species. Suspected vernal pools can be officially certified (recognized) by the Massachusetts Natural Heritage Program.

PHYSICAL CHARACTERISTICS OF LAKES

Geology

The origins of ponds and lakes are a marvelously diverse collection of geologic, biological and man-made processes. Some of the more common categories include tectonic land movements such as thrusts and faults (e.g., Lake Tahoe, Nevada), volcanism (e.g., Crater Lake, Oregon), fluvial (riverine) activity (e.g., The Oxbow, Northampton, MA) and glacial activity. The last category (glacial) was the predominant natural process forming lakes and ponds in Massachusetts. Typically lakes were formed by the damming of streams by glacial moraines, which are the rock and debris left behind after the glacier retreats. Alternatively, melting of large blocks of ice trapped in the glacial moraine lead to the development of kettle lakes, which are very common in the Cape Cod region. These processes are depicted in Figure 1.2. The most important recent agent for the formation of lakes is man. Impoundment of water for mechanical hydropower, water supply, flood control, recreation, and hydroelectric generation have produced a large number of the existing lakes and ponds in Massachusetts.

The importance of the underlying geology of a region to a lake is manifold. The bedrock and soil properties help to determine whether precipitation will percolate down to recharge the ground water or runoff over the surface into the lake. This helps to determine the source of water to a lake. For example, a kettle lake in a glacial outwash (sand and gravel) plain will be primarily supplied with water through ground water seepage. The impact of this on the hydrologic budget will be discussed in detail in a later section of this course.

A second and important influence of surrounding geology is on lake chemistry. As the water percolates or flows over the rock and soil, it weathers (dissolves) a small portion of the parent material. This dissolved portion becomes the initial basis for the resulting lake water chemistry. This helps to explain why some lakes are more susceptible to pH changes due to acidic precipitation, while others (often with appreciable limestone content in the watershed bedrock material) are not at risk. This natural lake chemistry is often significantly altered by human influence.

Size

The surface area of a lake (or Ao) is an important parameter as it influences the degree of lake/land interaction, the importance of atmospheric loadings (precipitation and dry fall), the number and variety of natural habitats, and the lake's cultural importance. Area is usually measured by planimetry, the tracing of the outline of the lake with a planimeter, a simple instrument that converts an enclosed space into areal measurement units. For accurate measurements, an USGS (United States Geological Survey) topographic maps or recent aerial photographs are preferred. Lakes with fluctuating water levels may show considerable variation in area over the season.

FIGURE 1.2
GLACIAL ORIGINS OF KETTLE LAKES.

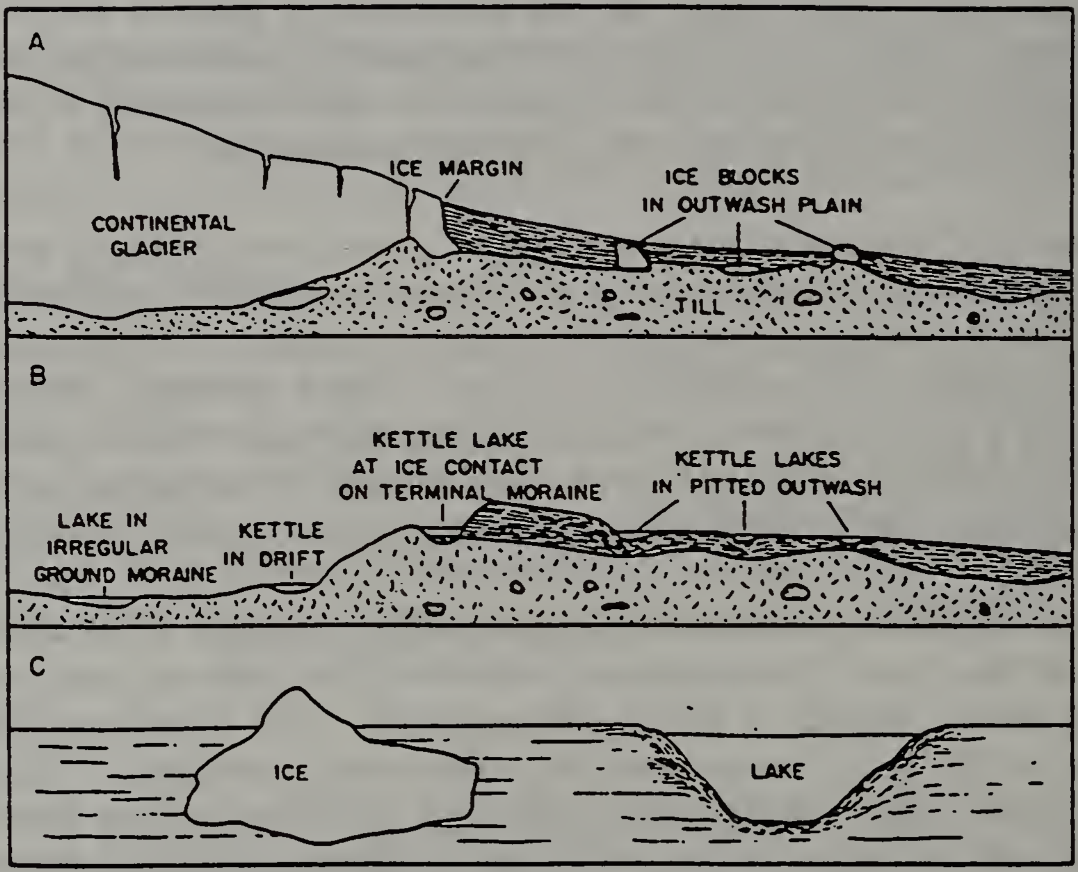

A
CONTINENTAL GLACIER
ICE MARGIN
ICE BLOCKS IN OUTWASH PLAIN
TILL
B
KETTLE LAKE AT ICE CONTACT ON TERMINAL MORAINE
KETTLE LAKES IN PITTED OUTWASH
LAKE IN IRREGULAR GROUND MORAINE
KETTLE IN DRIFT
C
ICE
LAKE

Figure . Diagram of formation of various types of kettle lakes. *A*, retreating continental ice, with outwash plain containing stagnant ice blocks. *B*, lakes formed in outwash and in till by melting of ice blocks, and as irregularity in ground moraine (after Zumberge). *C*, formation of slight shelf by melting of large, partly buried ice block, with much irregular sliding of outwash originally covering sides of block

SOURCE: Hutchinson 1957.

The volume (V) or capacity of the lake is also an important factor, as it helps to moderate the influence of surface runoff, provides dilution for contaminants, and determines the potential for water supply or flood storage. Basin volume is closely approximated by plotting the area of bottom contours, as closely spaced as possible, against depth and measuring with a planimeter. An example of a volume calculation is given on Worksheet 2.

The watershed area or drainage basin is an important determinant of lake quantity and quality. Delineation of the area of watershed is discussed in Section 2. Generally, the larger the watershed area, the greater the flow entering the lake system. The importance of land use in shaping the water quality of this water will be discussed in detail later in the text.

The amount of inflow from feeder streams (tributaries) into a lake helps to determine the degree of circulation or stagnation which will occur. A rough estimate of annual inflow (Q) can be derived by multiplying the watershed area (in square miles) by a watershed yield factor. For most parts of Massachusetts, a yield factor of 1.5 cubic feet per second/ sq. mile can be used as a first approximation. A sample calculation is shown in Worksheet 1. Note that this an annual inflow and is subject to considerable seasonal variation.

The flushing rate incorporates the amount of inflow with the lake volume to produce a measure of lake water exchange. The flushing rate is very important when trying to predict the effect on a lake of changing nutrient or pollutant loads, or anticipating the effects of diverting water away from a lake. Flushing rate is calculated as the volume of inflow per time divided by the volume of the basin. This produces a value of the number of exchanges per time. The mathematical inverse of flushing rate is lake residence time, or detention time which describes how long it takes for the lake to go through one complete exchange of water (see calculations on Worksheet 2).

Bathymetry

Other parameters commonly used to describe a lake include maximum depth and mean depth. Maximum depth or Zmax is simply the greatest depth of the lake. The mean depth or Zavg can be calculated by taking the volume of the lake and dividing by its surface area. In most cases, the lake biota and its subsequent management is more dictated by the mean depth of a system, rather than the maximum depth. Although, anglers commonly seek out the "deep holes" in lakes to find the fish which seek the colder bottom waters in the height of summer.

WORKSHEET 1 - EXAMPLE OF ANNUAL INFLOW CALCULATIONS

HYDROLOGIC CALCULATIONS FOR MAMANASCO LAKE, RIDGEFIELD, CT

1.) Unit Watershed Area Method.

a.) Watershed Area + Lake: 537 ac + 96 ac = 0.99 sq. mi.

b.) Use yield coefficients (Weiss, 1983) with watershed area.

Yield estimate = 1.58 cfs/sq. mi. x watershed areas (sq. mi.)

Mamanasco estimate = 1.58 cfs/sq. mi. x 0.99 sq. mi. = 1.56 cfs

2.) Runoff Estimate Method.

a.) Assume that certain portion of the precipitation is runoff that flows into surface tributaries. Add direct precipitation to lake and subtract evaporative loss. The runoff estimates used are from Higgins and Colonell (1971), and the average yearly precipitation is 47.1" or 3.93 ft/yr; as measured at Danbury, CT (SCS, 1981).

b.) High runoff range = 2.61 ft/yr x 537 ac = 5.450 10^7 ft^3/yr.

Low runoff range = 1.67 ft/yr x 537 ac = 3.906 10^7 ft^3/yr.

c.) Direct precipitation on Mamanasco Lake:

3.93 ft/yr x 96 ac = 1.643 10^7 ft^3/yr.

d.) Evaporation losses from Mamanasco Lake:

2.33 ft/yr x 96 ac = 0.974 10^7 ft^3/yr.

e.) Calculations :

54,500,000 + 16,430,000 - 9,740,000 = 61,190,000 ft^3/yr.

39,060,000 + 16,430,000 - 9,740,000 = 45,750,200 ft^3/yr.

f.) Range of flow estimates = 1.45 - 1.94 cfs

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Higgins G.R. and J.M. Colonell. 1971. Hydrologic Factors in the Determination of Water Yields. Water Resources Research Center. Amherst, MA.

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Weiss, L.A. 1983. Evaluation and Design of a Streamflow - Data Network for Connecticut. USGS and CT DEP. Connecticut Water Resources Bulletin #36.

WORKSHEET 2 - EXAMPLE OF LAKE VOLUME CALCULATION

ALDEN POND, LUDLOW, MA - VOLUME CALCULATIONS

DEPTH (ft)	SURFACE AREA A_o (ft^2)	PERCENT A_o	AREA AT DEPTH A_z	LAYER (ft)	VOLUME (ft^3)
0-3	162,914	0.85	138,477	3	415,431
3-6	162,914	0.58	94,490	3	283,470
6-9	162,914	0.24	39,099	3	117,298
9-11.5	162,914	0.03	4,887	2.5	12,219
					824,418

824,418 ft^3 = 19.02 acre-ft.

WORKSHEET 2 - EXAMPLE OF FLUSHING RATE AND DETENTION TIME CALCULATION

NASHAWANNUCK POND, EASTHAMPTON, MA - FLUSHING RATE

Assume that annual inflow equals flow through the system = 23.4 cu.m/min.
since 1 cfs = 1.7 cu.m/min this is equivalent to 23.4/1.7 or 13.8 cfs

Mean annual inflow = 23.4 cu.m/min X 60 min/hr x 24 hr/day x 365 day/yr
or 12,299,040 cu.m/yr

Assume lake volume equals 234,890 cu.m

$$\text{Flushing rate} = \frac{\text{inflow total}}{\text{Volume}} = \frac{12{,}299{,}040 \text{ cu.m/yr}}{234{,}890 \text{ cu.m}} = \underline{52.4 \text{ flushings per year}}$$

NASHAWANNUCK POND, EASTHAMPTON, MA - RESIDENCE OR DETENTION TIME

Assume that outflow equals flow through the system = 23.4 cu.m/min.

Assume lake volume equals 234,890 cu.m

Mean annual output = 12,299,040 cu.m/yr

$$\frac{234{,}890 \text{ cu.m}}{12{,}299{,}040 \text{ cu.m/yr}} = 0.019 \text{ yr} \times 365 \text{ day/yr} = \underline{7 \text{ days}}$$

The depth contours of the lake basin and their relative spacing help to determine the habitat value of the lake. For example, a relatively rapid drop-off of depth from the margin of the pond produces a narrow littoral zone and reduced biological activity. A good depiction of the rate of drop-off is provided by the hypsographic curve. This curve is usually drawn as a plot of percent of lake area overlying a given depth contour against depth. Figure 1.3 shows some examples of hypsographic curves from lakes of varying basin shape. Note the limnological convention of placing depth on the negative y-axis, such that the surface (depth or Z = zero) is at the top.

Other Useful Morphometric Parameters

Some other useful mathematical descriptors of a lake include shoreline length, shoreline development and maximum length. Shoreline length (L) is the linear distance of the intersection between land and permanent water. Shoreline development (DL) is the ratio of the shoreline length to the circumference of a circle of area equal to that of the lake. The further the shape of the lake departs from that of a pure circle, the greater the shoreline development value. It is of interest because it reflects an increased importance of littoral communities. The maximum length (ML), also known as the fetch, is the distance on the lake between the two most distant points. It represents the maximum length for wind to interact on the lake without interruption by land and is directly related to the ability to generate waves.

REGIONAL LAKE CHARACTERISTICS IN MASSACHUSETTS

Lakes of Massachusetts

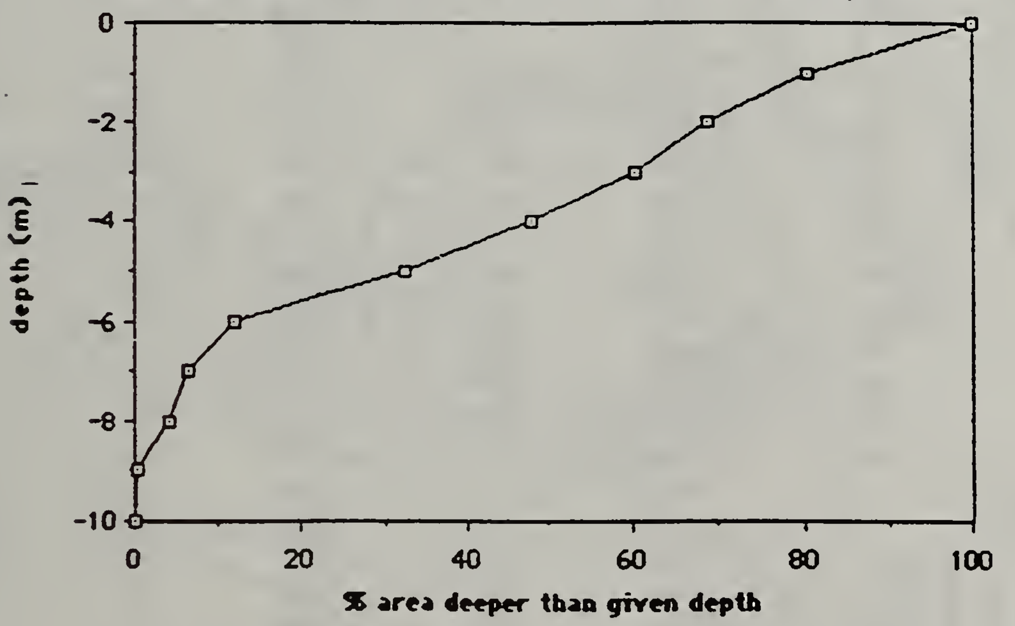
Massachusetts has a large number and wide variety of lakes and ponds. The Massachusetts Department of Environmental Protection (DEP) lists nearly 2,900 lakes and ponds which does not include many of the smaller and more remote water bodies. This total also includes 230 Great Ponds. The amount of acreage of "official" lakes and ponds is in excess of 150,000 acres. A summary of a statewide lake and pond inventory is given in Table 1.1.

River Basin Classification

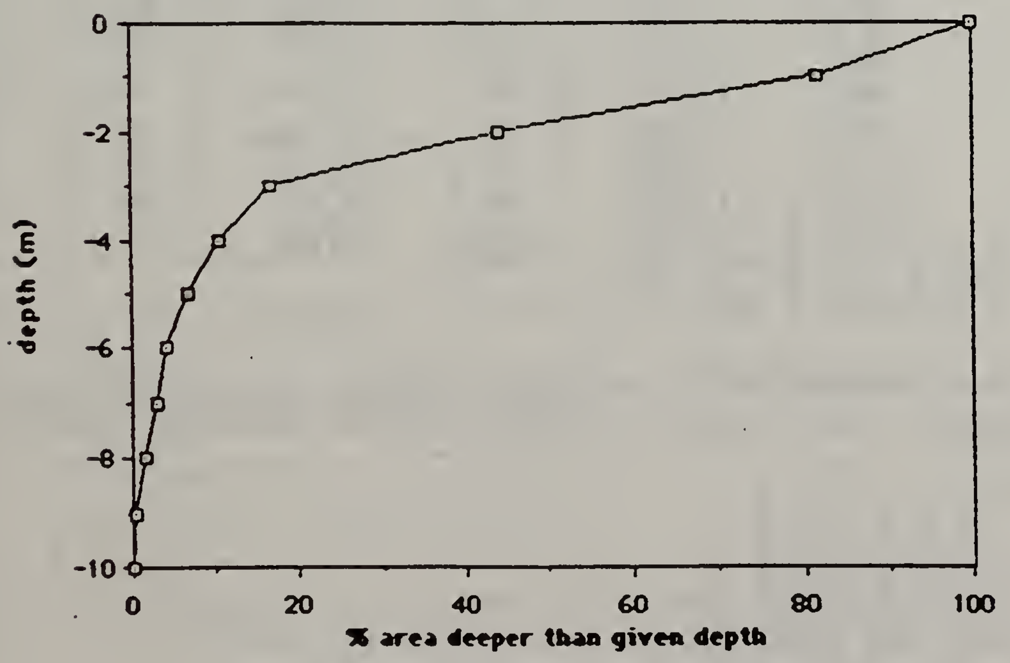
The information in Table 1 also includes classification of lakes and ponds by river basin and/or coastal drainage basin. The various river basins of Massachusetts are shown in Figure 1.4. Classification through location in a major river watershed basin provides a convenient and useful organizing principle. As can be intuitively grasped, lakes that are directly connected

FIGURE 1.3
HYPSOGRAPHIC CURVES FOR TWO MASSACHUSETTS LAKES.

Hypsographic Curve of Silver Lake, Wilmington, MA.



Hypsographic Curve of Lost Lake/Knopp's Pond



SOURCE: BEC.

TABLE 1.1

STATEWIDE LAKES AND PONDS INVENTORY*

SOURCE: MA DEP 1989.

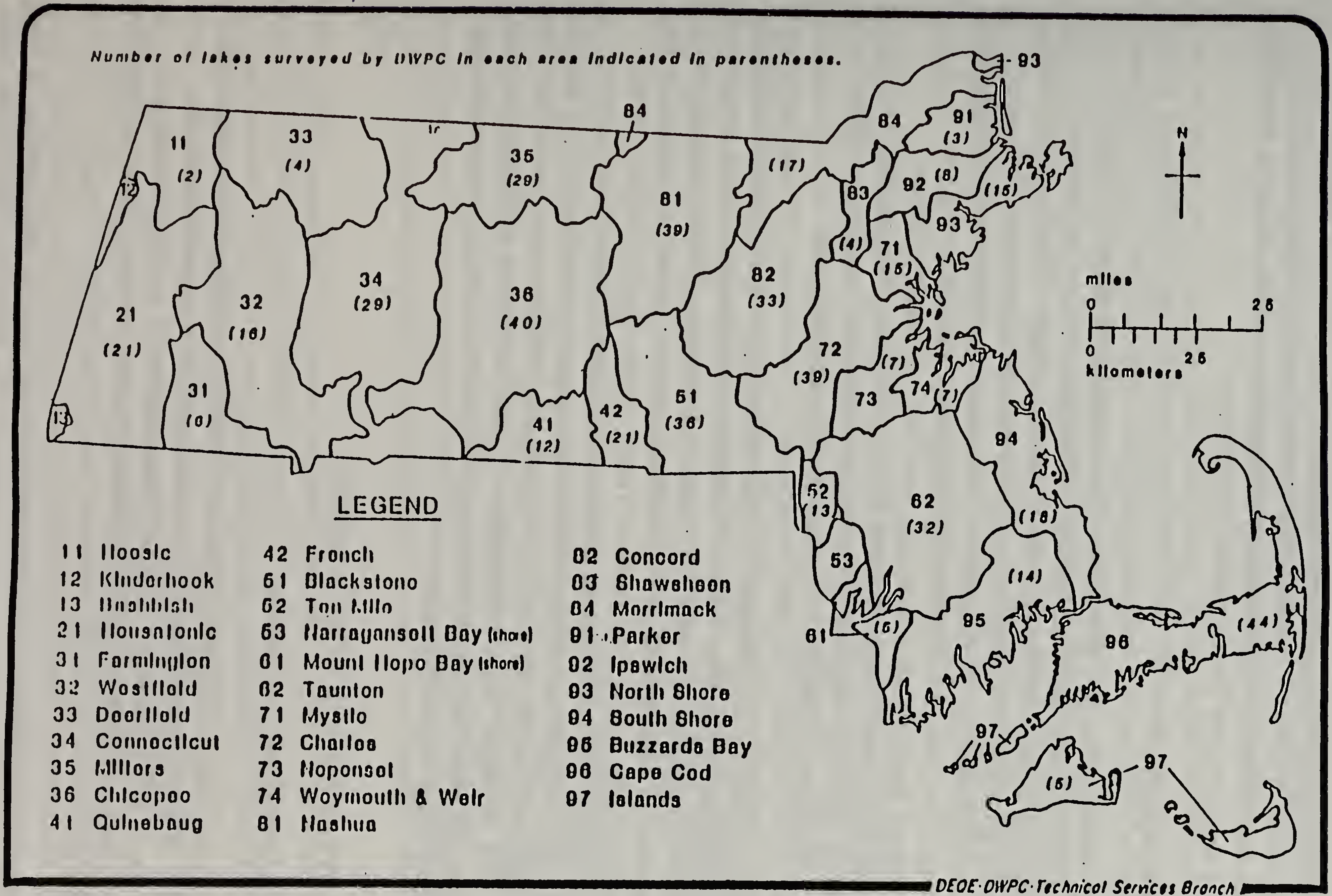
RIVER BASIN/ COASTAL DRAINAGE AREA	Category**					
	1	2	3	4	5	6
Hoosic (11)	17	625	8	597	—	—
Kinderhook (12)	4	28	1	10	—	—
Bashbish (13)	5	41	2	25	—	—
Housatonic (21)	118	5,184	72	4,969	17	2,882
Farmington (31)	50	3,583	35	3,497	2	394
Westfield (32)	79	4,550	50	4,395	10	1,059
Deerfield (33)	21	589	14	562	2	42
Connecticut (34)	103	2,992	49	2,741	4	239
Millers (35)	104	4,720	69	4,536	2	74
Chicopee (36)	166	31,837	104	31,496	14	1,305
Quinebaug (41)	55	2,406	33	2,303	7	612
French (42)	66	3,603	37	3,436	1	169
Blackstone (51)	185	7,267	108	6,891	8	2,060
Ten Mile (52)	42	1,301	22	1,185	—	—
Narragansett Bay (53)	5	146	2	135	—	—
Mount Hope Bay (61)	7	3,713	7	3,713	1	1,700
Taunton (62)	213	12,551	131	12,072	7	3,010
Mystic (71)	45	1,496	21	1,368	2	124
Charles (72)	142	3,708	64	3,358	12	834
Neponset (73)	61	1,879	26	1,700	2	43
Weymouth and Weir (74)	27	1,213	12	1,139	1	210
Nashua (81)	161	10,953	94	10,651	10	1,094
Concord (82)	127	7,456	80	7,209	13	829
Shawsheen (83)	19	552	10	506	4	187
Merrimack (84)	79	4,033	44	3,841	10	1,270
Parker (91)	17	316	9	273	3	132
Ipswich (92)	74	1,982	36	1,777	5	215
North Shore (93)	90	2,428	39	2,154	9	743
South Shore (94)	173	5,151	87	4,714	14	1,612
Buzzards Bay (95)	171	6,378	121	6,085	15	1,908
Cape Cod (96)	343	11,039	196	10,254	49	5,796
Islands (97)	102	7,453	55	7,263	6	826
TOTALS	2,871	151,173	1,638	144,855	230	29,419

* Table compiled from information in the Compilation of Lakes, Ponds, Reservoirs, and Impoundments, 1984. Mass. Division of Water Pollution Control.

** Numerical Legend:

1. Number of lakes and ponds
2. Surface area of lakes and ponds (in acres)
3. Number of lakes and ponds greater than 10 acres
4. Surface area of lakes and ponds greater than 10 acres
5. Number of officially recognized Great Ponds
6. Surface area of officially recognized Great Ponds (in acres)

Number of lakes surveyed by DWPC in each area indicated in parentheses.



DEQE·DWPC·Technical Services Branch

FIGURE 1.4

MASSACHUSETTS RIVER BASINS
AND COASTAL DRAINAGE AREAS

SOURCE: MA DEP 1989.

through riverine flow (i.e., one downstream of the other) will tend to be similar in water chemistry. Coordinated management of adjacent lakes is sometimes facilitated by regional planning agencies, which are often based on watershed limits rather than political boundaries.

Eco-Region Approach

A further extension of this principle of grouping lakes based on shared natural characteristics has been recently developed by the United States Environmental Protection Agency (Gallant et al., 1989). This is the so-called Eco-Region approach, which has been already applied in some Midwestern states. This approach is predicated on the notion that there are recognizable lake districts that, because of similar geology and soils, lake origins, meteorological patterns, and drainage, are likely to exhibit similar characteristics in water chemistry and fauna and flora. The purpose of establishing these eco-regions is that lake management could be further refined to account for regional characteristics and tendencies.

There are no defined Eco-Regions in Massachusetts, but they are anticipated to be established in the near future. Based on available data, work experience and simple conjecture, the author expects that a reasonable set of proposed Eco-Regions for Massachusetts would likely include 1) the Berkshires, 2) the Western Uplands, 3) the Connecticut Valley, 4) the Central Region, 5) the North Shore, 6) the Southeastern Coastal Plain, and 7) Cape Cod and the Islands. Each region has distinct differences in geology and soils and therefore lake origins and water density. These proposed regions could be further fine-tuned. For example, these Eco-Regions should be further differentiated with an overlay of land use, since the impacts of land uses can often overwhelm the background water chemistry.

LAKE STRATIFICATION AND MIXING

Important Properties of Water

One of the fundamental principles in the function of lakes is the seasonal layering of warm water over colder water known as stratification. To understand this somewhat complex phenomenon it is first necessary to review some of the important properties of water, namely those of light, heat and density.

Light or solar radiation is the ultimate driving force for this layering in lakes. Solar radiation is the direct source of heat in the water and also drives wind patterns, which creates waves and mixing in lakes. Further, the distribution of light in the aquatic environment also powers the photosynthetic machinery of green plants which produces biomass and oxygen.

Solar radiation entering a lake has many fates. It may be reflected back off the surface, absorbed and produce heat, scattered into different wavelengths or transmitted to the depths below. As light penetrates the waters of a lake it is rapidly absorbed and its intensity decreases exponentially, as shown in Figure 1.5. This loss of light is described mathematically by a lake-specific loss factor, the extinction coefficient, which is simply a value of the fraction of light that is held back per increment of depth. This loss of light intensity with depth may be charted with a submarine photometer (a waterproofed photocell) and the extinction coefficient determined.

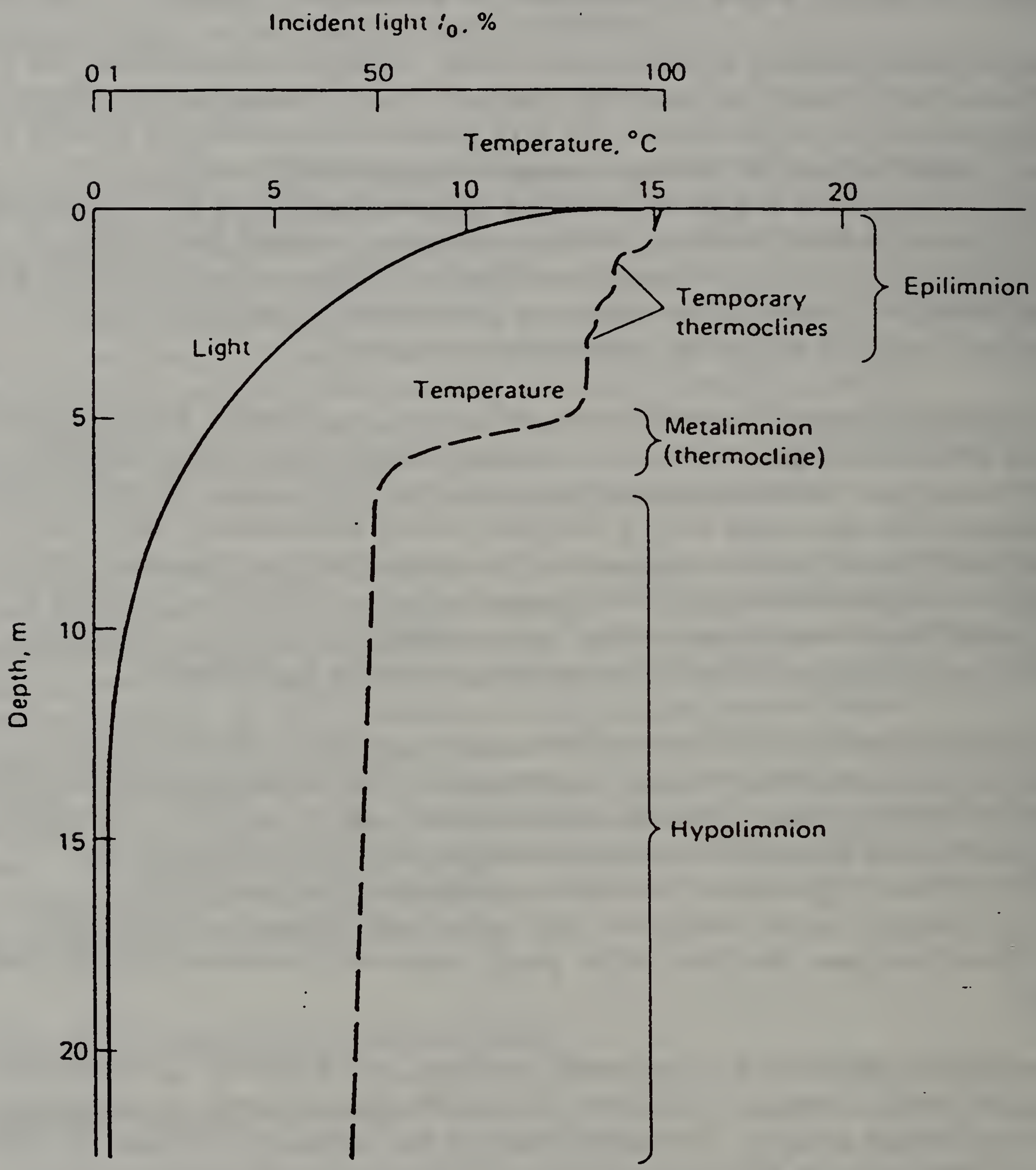
A simple, inexpensive tool which can be used to measure the transparency of a lake is the Secchi disk. This is a small (e.g., 20 cm) disk which is usually painted white or with alternating black and white quadrants. The Secchi disk is lowered into the water until it disappears from the observer's sight, and then slowly raised until it reappears. The distance halfway between these two points is considered the Secchi transparency depth. This value provides a quick and useful assessment of the light conditions in the lake. The photic zone is usually approximately two to three times the Secchi depth.

As the light penetrates the water, there is also a selective absorption of different portions of the spectra. In pure water, light is preferentially absorbed in the following order - infrared, red, ultraviolet, green and blue. However, in most natural situations, the selective absorption of blue light by the photosynthetic pigments of the minute, suspended microalgae (the phytoplankton), means that green light penetrates furthest. Accordingly, SCUBA divers near the limit of the photic zone are illuminated by dim green light.

Once light is absorbed it is converted into heat, and water has an enormous capacity for heat storage. However, the distribution of heat is not the same as the distribution of light. As sunlight falls on the surface of the lake, the upper waters are heated and become warmer and less dense with respect to the cooler, denser waters below. This is due to the relationship between water temperature and density. Density is generally inversely related to temperature (the lower the temperature, the denser the water), but is actually greatest at about 4^{o} centigrade (C), and decreases slightly at temperatures below that (this is why ice floats on the surface of water). This means that water at 4^{o} C is the heaviest and will sink to the bottom of the lake basin. It is

FIGURE 1.5

INTERRELATIONSHIP BETWEEN LIGHT AND HEAT IN LAKES.



SOURCE: Goldman and Horne 1983.

not surprising to learn that waters at the bottom of some of our deepest lakes (e.g., Lake Superior) rarely deviate much from this temperature.

Development of Summer Thermocline

As noted before, the formation of the thermocline each summer is the single most important event for the lake biota. With the increasing solar radiation the upper waters begin to warm and become increasingly differentiated from the bottom waters, due to convection currents and stirring by wind action. The resulting pattern is termed thermal stratification and partitions the lake into three distinct layers. These zones are the epilimnion--the upper warm, mixed layer; the hypolimnion--the cooler, more-dense bottom waters; and the metalimnion--a boundary layer that contains the thermocline, which is a region of rapid temperature change with depth. These zones are easily identified by examining a plot of temperature versus depth such as are shown on Figure 1.5.

The thermocline, once established by a temperature difference (only 2 to 3° C may be necessary), forms a fairly stable and effective boundary layer between the epilimnion and hypolimnion. While there is no visible barrier, the difference in densities between the two water masses is sufficient to prevent significant interchange of waters, gases (especially dissolved oxygen), and chemical materials between the two. It does not prevent decomposing particles from settling (falling) out of the epilimnion into the hypolimnion, nor does it prevent the migration of fish or larger invertebrates between the two. Most importantly, the hypolimnion is temporarily shut off from gaseous exchange with the atmosphere at the surface, its major source of dissolved oxygen. The continuing demand for oxygen for microbial decomposition of particles and the lack of resupply may cause hypolimnetic oxygen levels to decline over the summer, even to the point of near total exhaustion. When dissolved oxygen levels fall below about 0.5 mg/l, the waters are said to be anoxic. Under anoxic conditions, fish and other life are negatively affected (in some cases killed) and may actively avoid the area. More importantly, certain chemical reactions can take place in the absence of oxygen, and one of them, the liberation of phosphorus from the bottom sediments, may be significant in the resupply of this element to the lake's waters.

It should also be briefly noted that stratification in a lake can also occur through differences in chemistry rather than temperature. For example, some coastal ponds may have bottom saline waters from occasional marine intrusions. In these cases, the density barrier is caused by differences in the amount of dissolved substances, and the separating salinity gradient is termed the chemocline.

Annual Cycle of Mixing

Given the potential of the thermocline to shut off oxygen supply to the hypolimnion, one might suppose that the bottom waters of deep lakes would always be anoxic. However, this is not the case because stratification is a seasonal phenomenon and is interspersed with periods of lake mixing when there is a redistribution of oxygen throughout the water column. This sequence of mixing and stratification is fairly predictable for northern temperate climate lakes, such as exist in Massachusetts, and can be described as an annual cycle.

It is easiest to consider the annual cycle with a starting point in early spring (March or April), immediately after the melting and break-up of the winter ice layer ("ice-out"). At that time, water temperatures are uniform from top to bottom, a condition termed isothermal, and can be expected to be at or near 4^{o} C. This indicates that the lake or pond is in a state called the spring or vernal turnover (mixing), a period when there is free exchange of water and dissolved gases within the entire water column. It is a period where there is no perceptible biochemical zonation within the lake.

With the increasing solar insolation (April through June), the upper waters begin to heat up and the brisk winds of spring start to subside. Usually around May or June, a sufficient temperature difference exists between top and bottom and a thermocline develops, which strengthen over the course of summer due to the increasing temperature differences between epilimnion and hypolimnion. During the course of the summer the temperature of the epilimnion continues to climb, reaching a seasonal maximum usually in late July or August. Similarly, the depth of the thermocline increases over the summer, as the warmer layer increases in volume.

The lake begins to cool off in September, aided by decreasing solar radiation, cooling temperatures at night, and precipitation. The temperature difference between the epilimnion and hypolimnion begin to decrease as the thermocline is said to "erode". The erosion of the summer thermocline is usually complete by late September or early October. A return to isothermal conditions and another round of complete lake mixing denote the fall or autumnal turnover.

Cooling of the lake waters continues in October and early winter, and water temperatures are likely to remain close to isothermal throughout this period.

Freezing temperatures will cool the entire water column in December and January, with the development of ice occurring rather suddenly on a cold and still night. Ice cover increases over the winter and light levels within the lake are severely reduced. Because of the temperature of the ice, there is a tendency towards cooler water at the surface. This pattern is called inverse thermal stratification (cold water perched over warmer) and is not unusual for ice-bound temperate lakes. Again, it is caused by the irregularities of the temperature - density relationship of water. There is a weak partitioning of the water column and some restriction in mixing. However, this pattern of inverse stratification rarely develops as strongly as the summer thermal stratification and never survives beyond ice-out on a lake.

Usually by late winter or early spring the ice is in poor condition and thin enough that the increasing solar radiation starts to warm the underlying waters. That condition, coupled with heavy spring inflows and increased wind action leads to ice-out and a return to vernal turnover, completing the annual cycle of mixing. A graphical representation of this annual cycle is given in Figure 1.6.

Different Types of Mixing Patterns

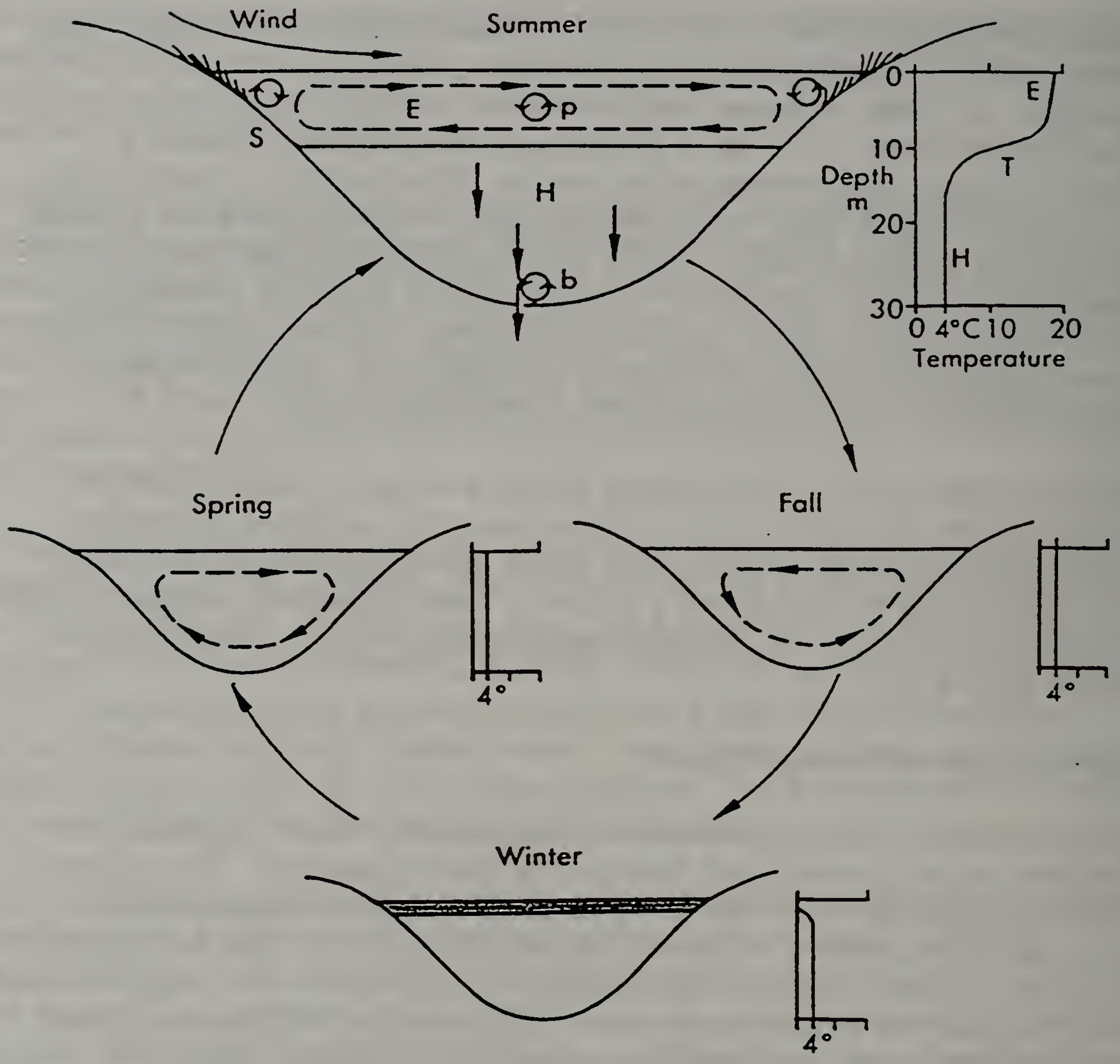
There are several different patterns of circulation for lakes. Most are dependent on the location and depth of the lake in question. The pattern of mixing described above, which has two periods of water circulation (the spring and fall turnovers) is called a dimictic circulation. This is the pattern for most of the deep lakes in New England. Lakes which mix only one period during the year are termed monomictic. This category includes very deep temperate lakes, polar lakes and sub-tropical lakes. Finally, there are polymictic lakes, which as the name implies, mix many times or nearly continuously through the year. Many of the shallower ponds and lakes in Massachusetts can be considered polymictic.

NUTRIENT AND CHEMICAL REGIMES

Cycling of Elements in Ponds and Lakes

The cycling of chemical elements within a pond or lake ecosystem is typically complex, due to the multiplicity of possible interchanges or transfers. These potential interactions include transfers between different water masses (e.g., tributary and lake, hypolimnion and epilimnion), between the atmosphere and water (e.g., rainfall, gaseous exchange), between land and water (littoral and pelagic, bottom sediments and hypolimnion), from any of those

FIGURE 1.6
ANNUAL CYCLE OF MIXING IN TEMPERATE LAKES.



Seasonal cycle in a temperate lake. **Summer:** The lake is stratified with a layer of warmer water (*E*, the epilimnion) on top of the colder and denser water of the depths (*H*, the hypolimnion). As shown in the temperature curve on the right, a layer of steep temperature change with depth, the thermocline, *T*, separates the warmer and colder water. Nutrient circulations are indicated by the smaller circles—*p*, the plankton; *s*, the shore community; and *b*, the benthos or bottom community. The friction of the wind causes the upper layer of water to circulate, so that nutrients are transported between the plankton and shore communities. Particles and organisms settle through the deeper water, carrying nutrients to the bottom, where they may be circulated between water and sediment, *b*, but where there is net movement into the sediment. **Fall:** The surface water cools until temperature is the same at all depths, and the whole lake is circulated by the wind. **Winter:** The water is stagnant and near 4°C., except close to the surface ice cover. **Spring:** The surface water warms until temperature is the same at all depths, and the lake is again circulated. Further warming of the surface water leads again to summer stratification.

SOURCE: Whittaker 1975.

compartments into the biota, and within the biota itself. The relative importance of each of these is highly variable, depending on the nature of the pond or lake in question. From a management viewpoint, several of these transfers are of more interest because of their significance to lake quality and their potential for possible control or reduction, while others (e.g., atmospheric interactions) are beyond the limits of local control.

With this management perspective in mind, it is useful to determine which nutrient (i.e., a required chemical element) may be in shortest supply in relation to the needs of plants (phytoplankton or rooted aquatic plants). For it is the relative abundance of this nutrient which will control or "limit" primary productivity (i.e. plant growth) in the lake or pond. That is, an increase in the amount of the limiting nutrient should result in a proportional amount of additional production, and vice versa. This limiting nutrient concept or "Law of the Minimum" is an important principle because it explains the response of a lake to increases in watershed pollution, but also indicates the priority of which elements should be reduce to effect a change in lake conditions. Note that not all limiting factors are nutrients, but can include physical factors such as light or temperature.

Phosphorus Cycle in Ponds and Lakes

In considering possible limiting nutrients, it makes sense to start with phosphorus, since it is the element most often "limiting" primary productivity in temperate zone lakes and ponds. Its scarcity is due to a relative lack of phosphorus-containing minerals, no atmospheric gaseous phase, and the fact that it is tightly bound by many common soil components. Thus, it is far easier to reduce or eliminate phosphorus inputs than to attempt to control other possible influences. Since phosphorus is likely to be a major control of biological growth in these systems it is the most appropriate target element for control in a lake or pond management program. This linkage has only been recognized relatively recently, particularly through a period of intense scientific research and debate during the late 1960's.

Scientists have discovered many different forms of phosphorus in the aquatic environment. The most important forms are orthophosphate, total phosphorus and particulate phosphorus. **Orthophosphate** (also known as soluble reactive phosphorus) is the major inorganic form of dissolved phosphorus most readily available for biological assimilation. Total phosphorus, as the name implies, refers to all the phosphorus in a volume of water including dissolved and particulate forms.

Most of the phosphorus in lakes occurs as particulate phosphorus in living or dead biomass, especially algae. If released (or remineralized) as inorganic orthophosphate upon the decomposition of organic material it is quickly taken up by bacteria, phytoplankton, or other plants. This rapid recycling occurs within the water column and is very efficient at keeping levels of measurable free dissolved phosphorus low in the water.

However, this recycling is not 100% efficient and some phosphorus is lost from the water column, either by particle settling or through precipitation by physiochemical means. Once at the bottom, phosphorus can be buried by sedimentation, translocated ("pumped") from the sediments by the roots of aquatic plants, resuspended by animal activity or wave action, or chemically regenerated in soluble form under anoxic conditions.

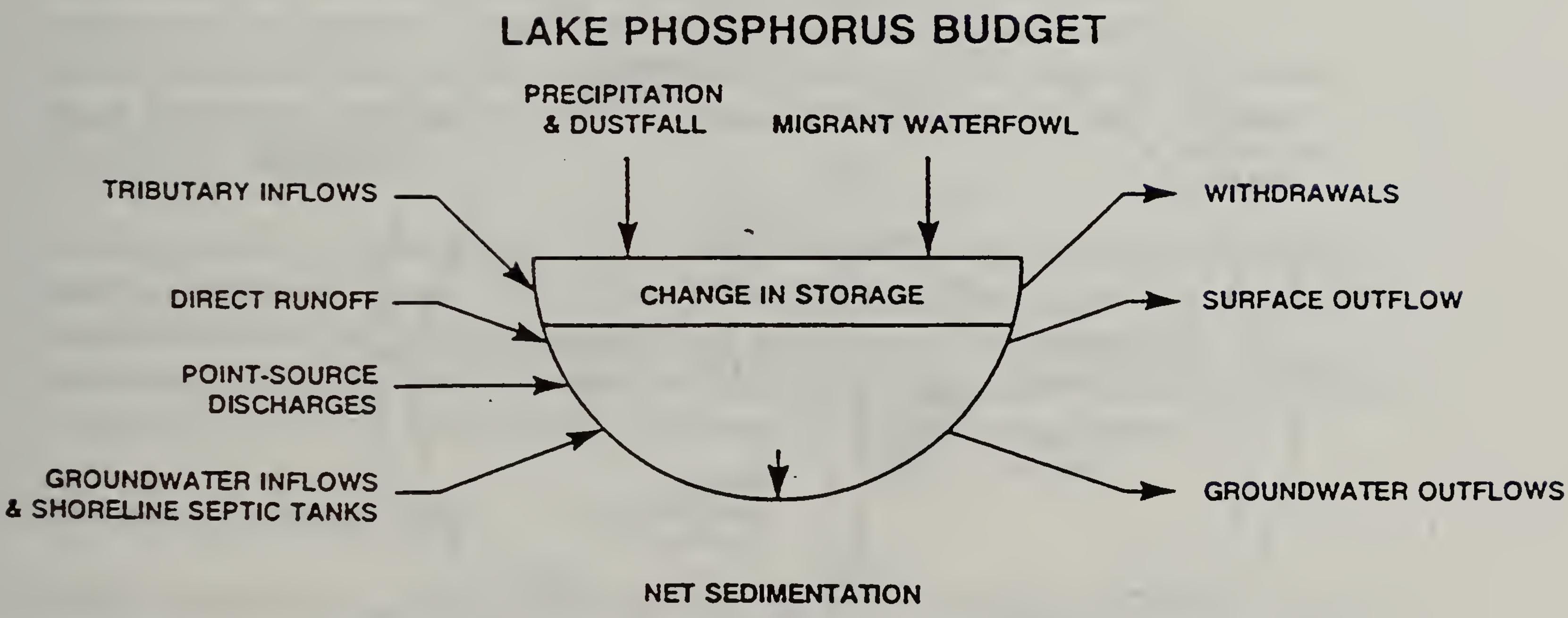
To counteract the loss to the sediments, additional phosphorus must be continually added to the system. The main inputs of phosphorus into lakes are from inflowing water (tributaries, overland flow and ground water) and (less importantly) rainfall and biota. Man has supplemented these natural sources in many cases. A schematic of the major flow of phosphorus through a lake system is shown in Figure 1.7.

Nitrogen Cycle in Ponds and Lakes

Nitrogen is another important plant nutrient and displays a more complex cycle in nature than phosphorus. Nitrogen inputs to aquatic systems are very difficult to control as a consequence of high nitrogen concentration in the atmosphere and the high mobility of nitrogen in the soil. The interconversion of various forms of nitrogen is readily accomplished by bacterial action as well. A depiction of the nitrogen cycle is shown in Figure 1.8. One important and unique nitrogen transfer is through nitrogen fixation, the conversion of atmospheric nitrogen gas into ammonia through enzymatic means. Nitrogen fixation is a process limited to bacteria and blue-green algae within the lake ecosystem, which can use it to supplement their internal nitrogen supplies under conditions of low nitrogen.

As shown in Figure 1.8, nitrogen occurs in three major forms in aquatic systems--ammonia, nitrate and organic compounds. A fourth form, nitrite is unstable and exists in very low concentrations for short periods of time during conversion between other forms. Ammonia and nitrate are readily available for uptake by plants. Both forms can cause toxicity problems at high concentrations. Ammonia is rapidly converted to nitrite and then nitrate in the presence of oxygen by naturally occurring bacteria, but the decline of

FIGURE 1.7
PHOSPHORUS BUDGET SCHEMATIC.



SOURCE: NALMS 1988.

FIGURE 1.8
NITROGEN CYCLE IN AQUATIC SYSTEMS.

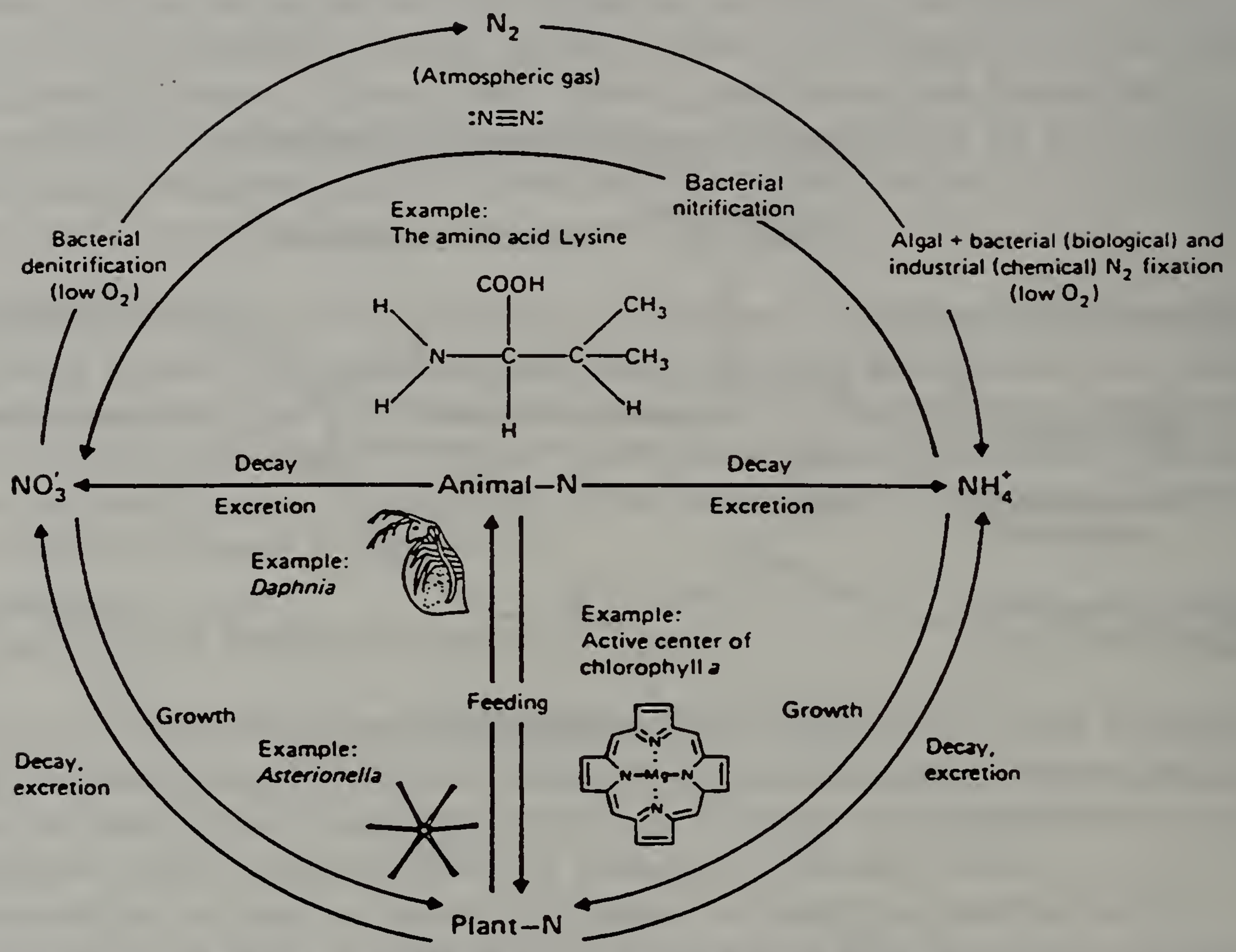


Figure Diagrammatic representation of the nitrogen cycle. Note the two anoxic one-way sections of the cycle (nitrogen fixation and denitrification) which involve procaryotic cells, in contrast with the reversible flows which occur in oxygenated conditions in the rest of the cycle. Denitrification ($NO_3 \rightarrow NO_2 \rightarrow N_2$) and nitrification ($NH_4 \rightarrow NO_2 \rightarrow NO_3$) which involve separate bacteria (see Table 11-1) have been simplified in this cycle. The roles of sediments are not shown in this figure. Most nitrogen in aquatic ecosystems is present as plant and animal nitrogen, e.g., as part of chlorophyll in *Asterionella*, or amino acids in *Daphnia*.

"Procaryotic" refers to cellular organisms with no distinct nucleus.

SOURCE: Goldman and Horne 1983.

oxygen during the summer in the deeper depths or wetland areas may promote the buildup of ammonia through decay processes.

While phosphorus is quite often the limiting nutrient, there are occasions when the relative supply of nitrogen temporarily limits primary production. One symptom of this nitrogen limitation is the nitrogen to phosphorus ratio (N:P ratio). The N:P ratio, indicates potential shifts in the chemical resources important to the primary producers. Examination of the empirical relationship between nitrogen to phosphorus ratios suggests that at values lower than 22:1 (atomic ratio), the supply of nitrogen may limit phytoplankton growth. Values greater than 55:1 are indicative of phosphorus-deficient ponds while those ponds whose ratios fall between these limits (i.e., greater than 22:1 and less than 55:1) may show variable patterns of limitation.

It is important to note that nutrient ratios alone do not provide conclusive proof of limiting factors, since other potentially limiting factors such as light availability may be contributing. Other considerations include the movement of the water through the impoundment, relative to the time scale of internal recycling or microbial processes (e.g. nitrogen-fixation).

Concept of Trophic State

When comparing lakes of similar morphometry but differing productivity, it soon became apparent to early researchers that the differences were related to the relative amount of nutrients entering a lake. A classification system developed based on the relative enrichment of a lake or its trophic state (i.e., condition of fertilization). Lakes were classified as either oligotrophic (poorly-fertilized) or eutrophic (well-fertilized). Lakes with intermediate characteristics were termed mesotrophic, while lakes or ponds which are extremely well-fertilized are hypereutrophic.

While the level of total phosphorus or available nitrogen is a good indicator of the degree of fertilization or eutrophication, it is not sufficient by itself. Therefore, determination of trophic state is usually not based solely on water chemistry, but includes such biological and physical parameters as chlorophyll a and Secchi disk transparency. One typical classification scheme is shown in Table 1.2. Other classification schemes include other indicators such as the presence of oxygen in the hypolimnion and the abundance of rooted macrophytes.

The trophic state classification has a useful, heuristic value in that it allows a simple categorization of an otherwise complex set of chemical and biological

TABLE 1.2

General Trophic Classification of Lakes and Reservoirs in Relation to Phosphorus and Nitrogen

PARAMETER (ANNUAL MEAN VALUES)	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC	HYPEREUTROPHIC
Total phosphorus (mg m^{-3})				
Mean	8.0	26.7	84.4	-
Range	3.0-17.7	10.9-95.6	16-386	750-1200
N	21	19	71	2
Total nitrogen (mg m^{-3})				
Mean	661	753	1875	-
Range	307-1630	361-1387	393-6100	-
N	11	8	37	-
Chlorophyll *a* (mg m^{-3}) of phytoplankton				
Mean	1.7	4.7	14.3	-
Range	0.3-4.5	3-11	3-78	100-150
N	22	16	70	2
Chlorophyll *a* peaks (mg m^{-3}) ("worst case")				
Mean	4.2	16.1	42.6	-
Range	1.3-10.6	4.9-49.5	9.5-275	-
N	16	12	46	-
Secchi Transparency Depth (m)				
Mean	9.9	4.2	2.45	-
Range	5.4-28.3	1.5-8.1	0.8-7.0	0.4-0.5
N	13	20	70	2

SOURCE: Wetzel 1983.

factors. However, since the system attempts to describe a wide spectra of conditions it is rarely a straightforward process except when dealing with lakes at the extreme ends of the conditions (i.e., oligotrophic, eutrophic). Further, too often lakes are classified on the basis of limited information, sometimes often only a single investigatory visit. Yet, the classification of lakes and ponds by trophic state provides a widely-accepted method of grouping lakes and ponds. It has been used by regulatory agencies for the purpose of inventorying water bodies in need of restoration or identifying lakes and ponds that may be particularly vulnerable to further loadings of fertilizers.

Other Important Elements

There are additional elements within lakes and ponds which are important for biological growth or chemical processes. These include calcium, important in providing buffering capacity to lakes; silicon, which is required by diatoms (an important algal group); iron and sulfur, important for chemical interactions; and molybdenum, needed for nitrogen-fixation. In rare instances shortage of these elements may temporarily limit production.

BIOLOGICAL LAKE COMPONENTS

Phytoplankton

Phytoplankton, or microscopic algae suspended in the water column, are an important component of aquatic food webs, but may also impart detectable color, odor, and taste to pond water as well as a reduction in water clarity. Phytoplankton biomass is often approximated by measuring the concentration of chlorophyll a, a pigment used in photosynthesis. It is the same pigment that makes grass and leaves green. Chlorophyll a concentration usually represents 0.5 to 2% of total phytoplankton biomass and has been correlated with production and standing crop at various levels of the food web, water clarity, and phosphorus concentration. Chlorophyll and non-living suspended solids are important determinants of water clarity.

The six major algal divisions include the diatoms (Bacillariophyceae), green algae (Chlorophyceae), blue-green algae (Cyanophyta), golden-brown algae (Chrysophyceae), cryptophytes (Cryptophyceae), and dinoflagellates (Pyrrophyta). Nuisance algae will be considered later in this text.

The nature of the phytoplankton community varies dramatically with time over the course of the year in what is usually termed the seasonal succession.

The typical seasonal progression of dominant algae in a temperate lake is diatoms and cryptophytes (spring to early summer), green algae (summer), blue-green algae, dinoflagellates (late summer through early fall), diatoms and chrysophytes (late fall) and flagellated forms during ice-cover. A typical seasonal succession is indicated in Figure 1.9. However, the nature of the phytoplankton in any specific pond reflects the response of the plankton community to changing physical, chemical, and biotic factors which may be specific to that year and that waterbody.

Zooplankton

The floating microscopic animals of zooplankton are of interest because they represent the linkage between the bottom of the food base and higher trophic levels, namely planktiverous fish. Typical zooplankton include rotifers, cladocerans, and copepods. Zooplankton are found in greatest numbers during early summer when they can substantially reduce the biomass of phytoplankton by their grazing, sometime resulting in a brief period of improved water clarity (the "clear water phase"). On the other hand, the zooplankton community is often impacted heavily by fish predation.

Macrophytes

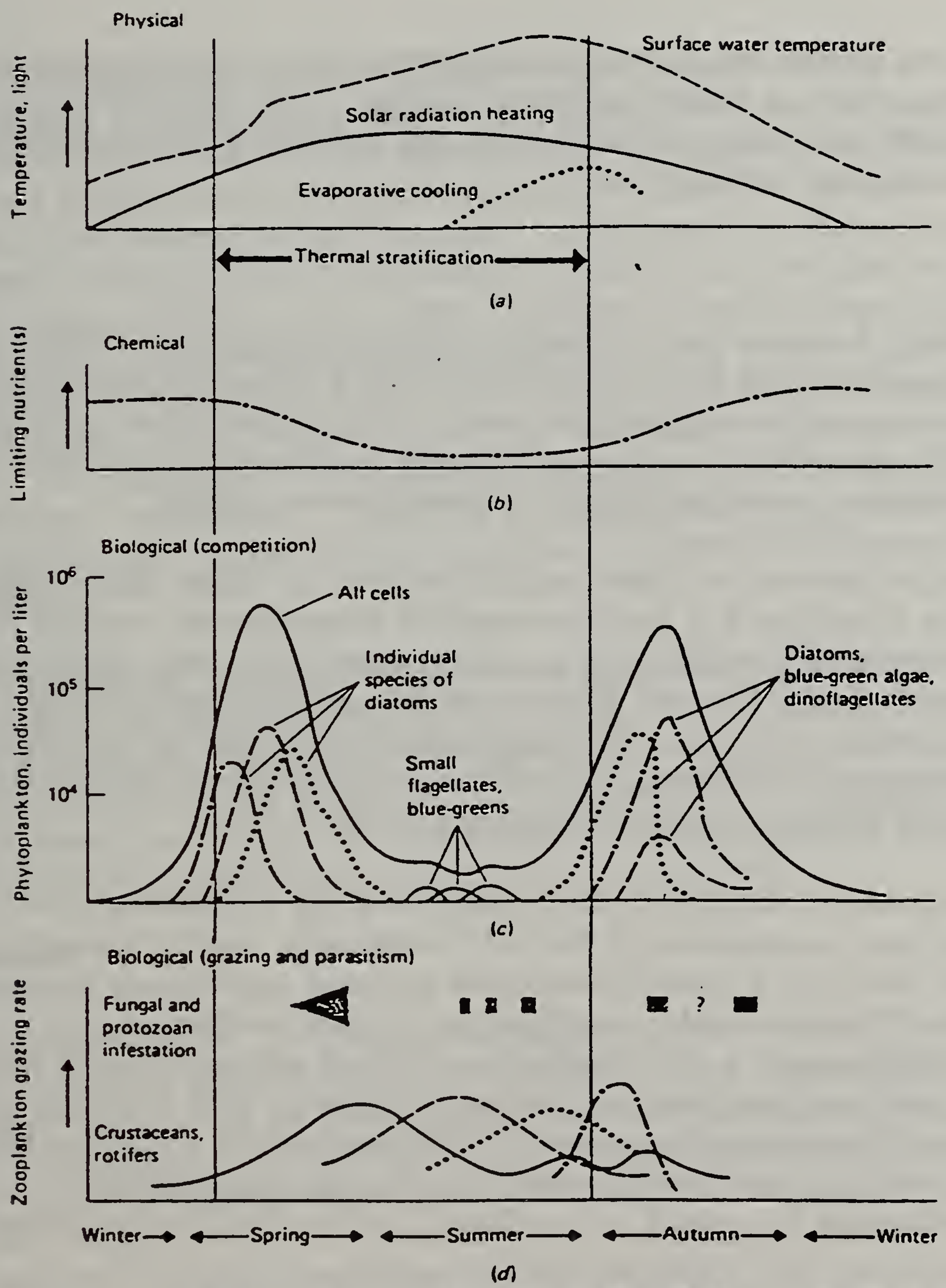
Macrophytes refer to the more complex aquatic plants found within or on the margins of aquatic environments. These plants may or may not have roots and can be broadly grouped into three categories based on their habitats - the emergent plants, the floating-leaved plants, and submerged plants. Macrophytes are critical elements of the littoral zone, providing structure and habitat for fish and invertebrate communities, and helping to mediate some of the nutrient interactions between the land and water. Further information is available in the laboratory section dealing with macrophyte identification.

Benthic Community

This simply refers to the community of animals that inhabits the submerged surfaces of lakes and ponds and includes a diverse group of animals including many insect forms (both larval and adult forms), such as true flies (Diptera), dragonflies (Odonata), mayflies (Ephemeroptera), caddisflies (Trichoptera), beetles (Coleoptera), and true bugs (Homoptera). Other typical invertebrate inhabitants included amphipods, isopods, snails, leeches (Erpobdellidae), oligachaetes (Oligochaeta) freshwater mussels and crayfish (Cambaridae). This community is particularly important in the processing and decomposition of organic material and may help facilitate nutrient or pollutant regeneration through tunneling or boring activity (bioturbation).

FIGURE 1.9

PHYTOPLANKTON SEASONAL SUCCESSION AND CAUSAL FACTORS.



Physical
Temperature, light
Surface water temperature
Solar radiation heating
Evaporative cooling
Thermal stratification
(a)
Chemical
Limiting nutrient(s)
(b)
Biological (competition)
Phytoplankton, individuals per liter
10^6
10^5
10^4
All cells
Individual species of diatoms
Small flagellates, blue-greens
Diatoms, blue-green algae, dinoflagellates
(c)
Biological (grazing and parasitism)
Zooplankton grazing rate
Fungal and protozoan infestation
?
Crustaceans, rotifers
Winter Spring Summer Autumn Winter
(d)

Figure Schematic diagram of the interacting (*a*) physical, (*b*) chemical, and (*c*) and (*d*) biological forces which control phytoplankton seasonal cycles. The major physical effect is the increase of sunlight which is sufficient for high rates of photosynthesis even in late winter. Not until the sunlight heats the lake to allow thermal stratification can high growth rates occur since until then plankton are often mixed below the photic zone. Temperature alone has little effect on phytoplankton cycles. Once stratification has occurred the supply of nutrients to the epilimnion is cut off, and one or more may successively or alternately limit daily growth. Temperature is important in controlling zooplankton grazing and parasitic attacks which occur mostly during the stratified period and may sometimes deplete algal populations. The diatoms in spring enjoy high nutrients, adequate light, and, at least initially, low grazing or predation. Zooplankton do not usually feed on large algae. Small summer blooms of large blue-green algae or rapidly reproducing small flagellates avoid or outgrow predation, and nutrients may recycle rapidly at low concentrations. The loss of thermal stratification in the fall due to evaporative cooling increases nutrients, light is still adequate, but the higher temperatures allow zooplankton grazing and perhaps parasitism to play a larger role. Thus large algae such as blue-greens and dinoflagellates are present as well as diatoms.

SOURCE: Goldman and Horne 1983.

Bioturbation can expose sediments and nutrients, that would otherwise be buried, allowing them to reenter the water column. This disturbance of bottom sediments by benthos is analogous to the aerating actions exerted by earthworms tunneling through loam.

Fish

Fish are generally a lake or pond's biota of greatest recreational interest. A thorough discussion of the function and role of fish in aquatic environments is beyond the scope of this primer. However, some of their prime attributes include a trophic position that couples the lower food web directly with man and their function as mobile indicators of general water quality.

Fisheries in Massachusetts are commonly referred to as either warmwater or coldwater. The latter (since it includes sensitive trout species) requires more pristine environmental conditions (e.g., cool temperatures, clear water, high dissolved oxygen levels) than do warmwater fish communities. These conditions are not common in most man-made lakes or may be met for only relatively brief periods of the year. Therefore, stocking and fishing for trout may be restricted to brief periods in the spring or fall.

Similarly, it should be recognized that trophic state has a profound effect on the abundance and composition of the fish community. With increasing eutrophication, levels of primary production increase, particularly among the phytoplankton. The increased production has a positive effect on fish growth, since they occupy a high position in the food web and benefit from the increased stocks of zooplankton, macroinvertebrates, and smaller bait fish (e.g., minnows). In general, the amount of fish produced in a pond or lake will increase with higher nutrient levels. The heavily fertilized and amazingly productive fish ponds of Southeast Asia are an extreme example of this principle.

However, these increases in primary productivity are not without significant change to the fish habitat. Characteristic changes in the water quality may include greatly decreased and/or fluctuating oxygen levels, high turbidity eliminating deeper submerged macrophytes, physical smothering of spawning areas with fine silts, and other water quality problems. Further, as vegetation increases, there is additional refuge and habitat for the bait fish. This sponsors their growth at the expense of game fish due to competition for food resources and their predation on game fish fry (young-of-the-year).

In response to changes in trophic state, there is often a shift in the composition of the resulting fishery. Sensitive species such as trout are replaced by more tolerant bass and panfish. As eutrophic conditions increase there is a selection for the most tolerant fish species such as carp or white suckers, often referred to as "trash fish". A hypothetical shift of species in response to trophic state is illustrated by Figure 1.10. Therefore an unmanaged, eutrophic pond or lake will tend to produce large numbers of fish, but few of the species sought by anglers. Some lakes manage to combine the benefits of high primary production without an accompanying deterioration of water quality, i.e., a large food base without poor oxygen levels. This can occur with a high flushing rate or a highly developed zooplankton community. While not common, these water bodies constitute some of the most successful and important recreational fisheries in the Northeast.

Another common grouping of fish is into game fish, panfish, and forage fish groupings. Typical game fish are brook trout, rainbow trout, brown trout, chain pickerel, northern pike, largemouth bass, smallmouth bass and walleye. Typical panfish include yellow perch, white perch, black crappie, bluegill, pumpkinseed, and brown bullheads. The forage fish category includes the various minnows and shiners, white suckers, and carp.

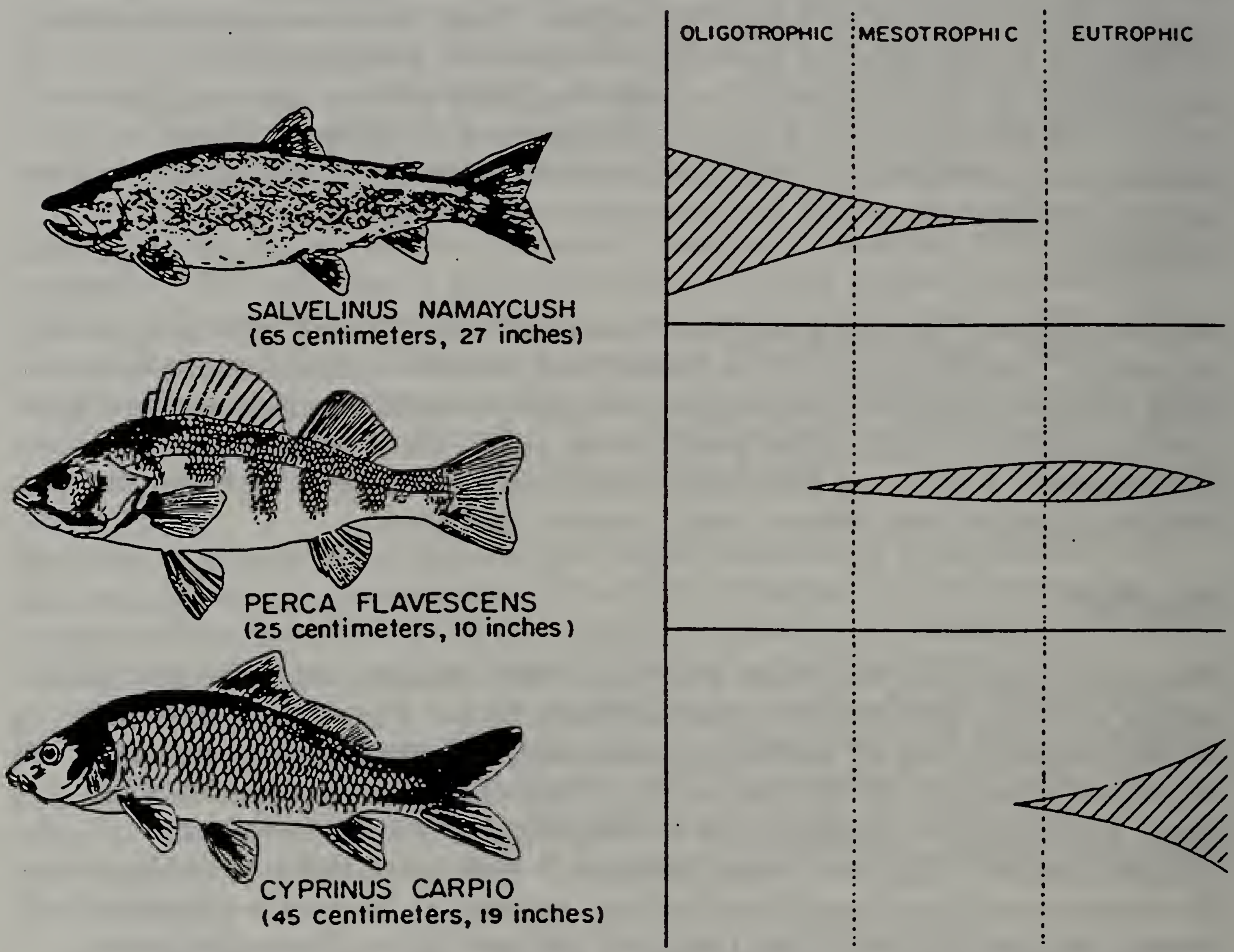
Waterfowl

Waterfowl connected with lakes and ponds in Massachusetts include a wide variety of ducks, geese, herons, and shoreline birds. They utilize lakes and nearby wetland areas for feeding, concealment, breeding, nesting, and as migratory reststops. While they occupy a higher trophic position, they are rarely critical to lake function, due to their relative few numbers and transient nature. However, their presence is sometimes taken as evidence of the existence of highly specialized habitat conditions. In certain restricted waters, resident waterfowl can become a problem due to their elimination products, which can provide nutrients to the lake and increase the concentration of bacteria and viruses in the water.

Other Associated Wildlife

This includes a variety of wildlife forms, including amphibians (frogs, salamanders), reptiles (turtles, watersnakes), and mammals (beaver, muskrat, otter). Of the latter, the beaver is especially important for management due to its ability to regulate local water levels by damming streams and other watercourses. Several of these species can represent significant sources of nutrients, bacteria and viruses.

FIGURE 1.10
INFLUENCE OF TROPHIC STATE ON FISH SPECIES COMPOSITION.



Relative abundance of three species of fish in oligotrophic, mesotrophic, and eutrophic lakes: Salvelinus namaycush (*lake trout*)*;* Perca flavescens (*yellow perch*)*;* Cyprinus carpio (*carp*)*. Designed by Dr K. Patalas.*

SOURCE: Vallentyne 1973.

LAKE SUCCESSION

Lake Ontogeny

Despite their importance in man's cultural landscape, most lakes are ephermeral or temporary in the vast geologic timescale. None of the lakes in Massachusetts pre-date the last retreat of glaciation (Wisconsin) nearly 12,000 years ago. Further, the rate at which lakes change with time is variable, depending on the size and nature of their watershed, their original morphometry, and climatological factors, especially temperature and rainfall.

The ontogeny of lakes concerns the successional development of lake ecosystems. This succession usually refers to a sequence of predictable geological events spanning from the creation to the destruction of a lake. We have previously considered some of the creative processes, such as volcanism and glacial activity. The destruction (or more rightly, transformation) occurs through a progressive accumulation of sediments in the lake basin, with an accompanying trend towards a more terrestrial situation. The basic driving forces behind this natural process are rain and gravity, as erosion frees particles which are ultimately transported downslope to accumulate in the lake basin. It is the same principle man attempts to copy in the use of sedimentation basins to trap eroded materials.

Following this concept, a deep lake becomes shallow over time, the shallow lake becomes a wetland, and the wetland slowly acquires upland characteristics. Many of today's forests and meadows in mountainous areas were once mountain lakes. Concurrent with these changes in lake basin dimensions, there is a predictable shift (successional) in the plant and animal communities.

The rate of lake ontogeny is very much influenced by the amount of nutrients entering the lake ecosystem. A newly created deep lake (e.g., Quabbin Reservoir) rapidly equilibrates with its nutrient loading over a period of decades to produce an initial state, quite often oligotrophic. This trophic state is characterized by low primary productivity and low levels of sedimentation. Over time, progressive erosion of the soils and landscape within the watershed leads to an increased rate of transfer of nutrients and sediments to the lake. As the lake basin is filled in, the ratio of watershed area to lake volume increases, meaning that nutrients will be diluted with less water. This produces higher concentrations of nutrients in the water column. In response, the lake becomes more mesotrophic in nature with increased plankton production and sedimentation rates. This shift (from mesotrophic to oligotrophic) is fairly slow and may be hundreds to thousands of years in duration.

However, if these trends do continue, the increasing nutrient levels will create eutrophic conditions. Higher levels of primary production occur. In contrast to the progression to mesotrophy, the shift to eutrophic conditions may be very rapid (decades to hundreds of years). The process is greatly accelerated by the increasing shallowness, enlargement of the littoral zone, and development of large macrophyte communities. The macrophytes increase in-lake organic production, redistribute nutrients within the lake ecosystem (by translocation), and provide more effective trapping of eroded materials entering the lake. These higher levels of sedimentation will fill in the basin and provide additional new habitat to macrophytes. Expansion from the margins by rooted macrophytes constricts and eventually chokes the open-water habitat with plant growth.

Cultural Eutrophication

Following the precepts of lake succession, it would seem that every lake is fated to eventually become a terrestrial meadow. This is not so, since some lake basins are so large and deep (e.g. Lake Superior, Lake Tahoe) that it would require entire geological epochs to fill in. In fact, many of the current deeper lakes are unlikely to complete a full succession before the next glaciation period occurs. Nor is it a unidirectional process, as given a shift in nutrient levels, lake succession may stall or sometimes even reverse itself. What is of interest to man is the shallower lakes and ponds which are undergoing extremely rapid change, usually in direct response to human influence.

We have described the progressive fertilization or eutrophication accompanying natural lake succession and indicated how it changes the physical, chemical, and biological character of the lake. Over the last two thousand years, the timescale of these changes have been significantly shortened in many waterbodies through human intervention (Figure 1.11). The causative process, cultural eutrophication, is the term given to the accelerated change in lake conditions caused by the by-products of human use of the watershed landscape. These by-products included increased nutrient loadings due to sewage discharges, septic system leachate, industrial processes, road runoff and agricultural practices, as well as increased sediment loads due to forest clear-cutting, agricultural erosion, storm drainage and building activities. Many of these sources are diffuse in delivery to the lake and are called non-point sources. Control of non-point sources is a critical aspect of watershed management, which is to be discussed later in this course.

Cultural eutrophication is an important problem for lake managers as it foreshortens the useful life of many lakes and ponds and can eliminate significant open water recreation within years to decades. The rapid increases in nutrients can lead to the creation of hypereutrophic conditions, marked by massive phytoplankton blooms, low oxygen and transparency levels and summer fishkills. Such conditions radically reduce the aesthetic or recreational utility of a waterbody. As noted above, lake succession can be reversed, but in the case of cultural eutrophication, such reversal may often only be gained at the cost of an expensive lake restoration program.

FIGURE 1.11 . EUTROPHICATION PROCESSES IN LAKES.

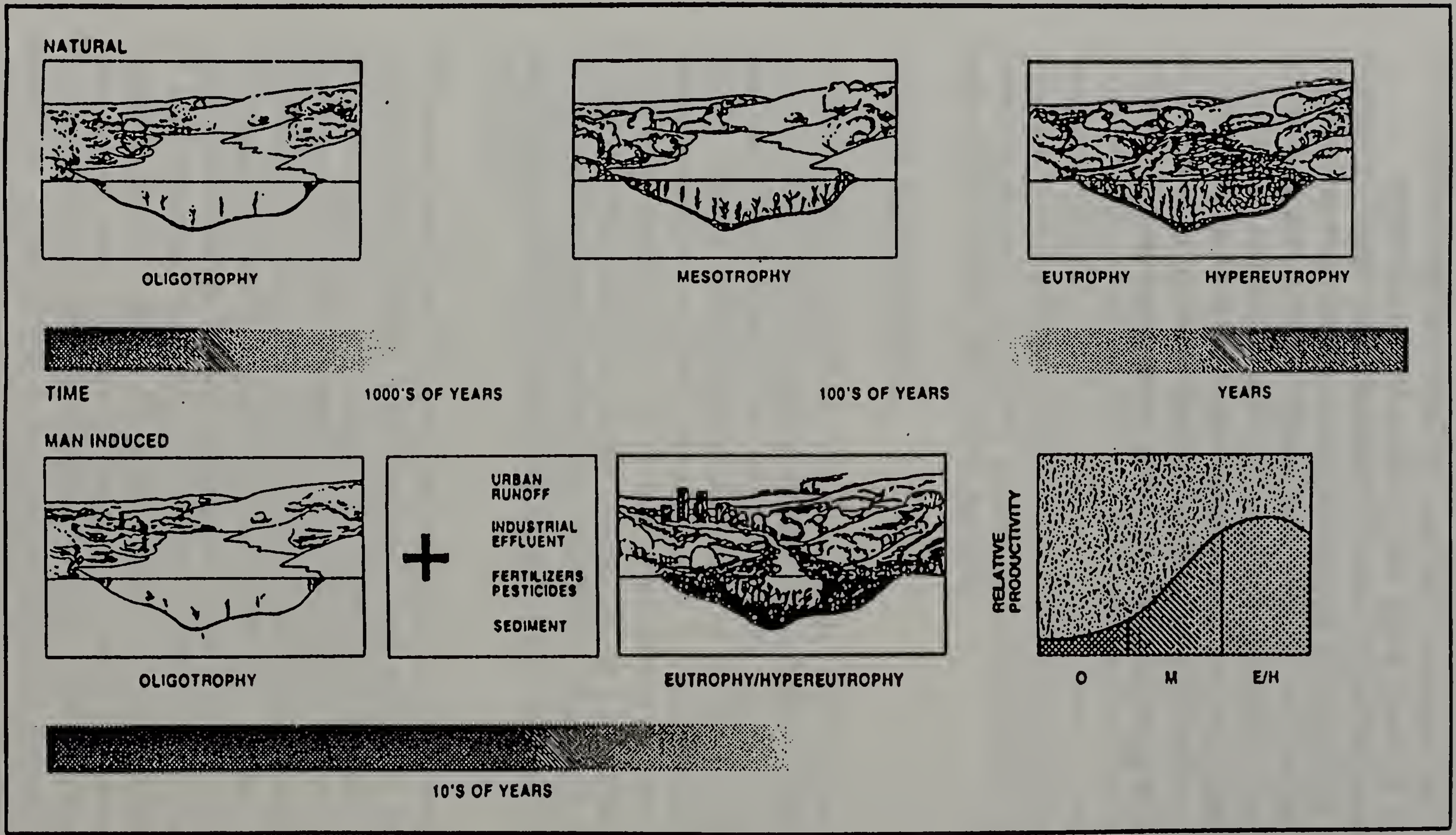


Figure - .–Above: The progression of natural lake aging or eutrophication through nutrient-poor (oligotrophy) to nutrient-rich (eutrophy) states. Hypereutrophy represents extreme productivity characterized by algal blooms or dense macrophyte populations (or both) plus a high level of sedimentation. The diagram depicts the natural process of gradual nutrient enrichment and basin filling over a long period of time (e.g., thousands of years).
Below: Man-induced or cultural eutrophication in which lake aging is greatly accelerated (e.g., tens of years) by increased inputs of nutrients and sediments to a lake, as a result of watershed disturbance by man.

SOURCE: NALMS 1988.

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SECTION 2.

INTER-RELATIONSHIPS BETWEEN LAKES AND THEIR WATERSHEDS

LECTURE OUTLINE

SECTION 2: WATERSHED FUNCTIONS & LAKE - WATERSHED .INTERRELATIONSHIPS

1. WATER AND THE HYDROLOGIC CYCLE

a. Hydrologic cycle

1. Inflows:
    - precipitation: snow, rain, hail,
    - tributary flow: feeder stream flow,
    - overland flow: rain-induced surface flow (runoff),
    - ground water flow: from upgradient recharge areas.

2. Outflows:
    - evaporation from open water surfaces. Ground water outflow: infiltration into downgradient soils or bedrock,
    - stream flow from draining streams,
    - transpiration: uptake and respiration by plants.

b. Watersheds and Drainage Basins

Watershed is the land area from which water drains to a lake (or stream). It consists of two components:

1. Surface Drainage Basin is the land area from which all surface water drains to a lake or stream at a lower elevation.

2. Ground Water Drainage Basin is the land area and associated subsurface through which ground water drains to a lake or stream at a lower elevation.

c. **Hydrologic Budget** quantifies the inputs and outputs of the hydrologic cycle for lake system over a suitable time period. A hydrologic budget is necessary before evaluating nutrient pollutant loadings to a lake system.

2. SURFACE DRAINAGE BASIN

a. Characteristics

1. Area: Size in square miles, kilometers or similar units categorized as open water or land.
2. Soil types and erodibility: critical for determining appropriate land uses and erosion control.
3. Types and extent of vegetative cover: input to estimating runoff and evapo-transpiration.
4. Types and extent of developed areas: categorization as agricultural, industrial, conservation, and residential uses critical to assessing potential water quality impact problems.
5. Average and maximum slope: input to estimating time of concentration and erosion potential.
6. Time of concentration: the time for a rain or water drop to travel from the furthest end of the watershed to the lake.

b. Delineation of surface drainage basins

Draw watershed divide boundaries on appropriate scale topographic map using two simple rules:

1. Draw divide boundaries perpendicular to contour lines.
2. Draw divide boundaries through the center of contour saddles and closed contour loops.

3. GROUND WATER DRAINAGE BASINS

a. Ground Water

Water which saturates pore spaces between gravel, silt, sand, or clay particles or in bedrock fractures in the subsurface environment.

- unsaturated (aerated) zone
- saturated zone
- Water table = upper elevation of saturated zone.
- Derived primarily from precipitation which has infiltrated into the subsurface environment.
- Ground water quality may be influenced by the types of geologic deposits.
- Porosity describes the void volume of a geologic material, i.e., the amount of air or water-filled voids within a unit volume of material.
- Permeability is a measure of a geologic material's ability to transmit water.
- High porosity materials, like clays, may be very impermeable because the voids are not interconnected.
- Aquifers hold and transmit sufficient quantities of ground water to permit economic development.
- Confined aquifers have impermeable confining layers above and below the aquifer materials; the water table elevation may rise above ground level if the upper confining layer is penetrated by a well.
- Perched water table: a layer of saturated soil formed on a low permeability layer located above the main water table.

- Ground water moves from higher water table elevations to lower water table elevations;

- Flow is a function of elevation and pressure differences and properties of the soil or bedrock matrix (hydraulic conductivity);

- Ground water flow is three dimensional: downwelling usually occurs at the higher elevations of a recharge area while upwelling usually occurs at the lower elevations of a recharge area.

- Ground water velocities are slower than surface water velocities, typically varying between several feet per day to several feet per year.

- Baseflow: ground water discharge into lakes and streams.

- Interflow: horizontal ground water movement through the unsaturated zone.

b. Ground Water Drainage Basins

Characteristics

- Soils: Types and extent (SCS soil maps);

- Geology: unconsolidated sediment versus bedrock types; fractures and faults; history of glacial, wind or stream action; depth to bedrock;

- Hydraulic conductivity: location and extent of high, low and non-permeable geologic formations;

- Presence of "losing" or "gaining" surface water bodies;

- Aquifers: volume and areal extent of each type: confined, unconfined and perched;

- Time of travel.

Tools and Methodologies

- Unconsolidated Sediments versus Bedrock

- Hydrogeologic Investigations: USGS atlases & geologic quadrangle maps

- Drilling

- Wells and Piezometers

- Water Table Elevation Maps

- Geophysical Investigations

- Delineation

4. TYPES OF WATERSHEDS

- Surface Water Dominated Watersheds
  Example: Richmond Pond, Western MA
- Ground Water Dominated Watersheds
  Example: John's Pond, Mashpee
- Mixed Surface/Ground Water Watersheds

5. SOURCES AND ATTENTUATION OF CONTAMINANTS

a. Pollutant/Contaminant Transport and Attenuation

- Adsorption/Absorption
- Dissolved transport
- Volatilization
- Biological assimilation
- Biological transformation

b. Point Source Contamination

- Industrial, Commercial and Residential Wastewater Discharges
- Stormwater Overflows
- Injection Wells

c. Non-Point Source Contamination

Septic Systems:
- Important source of nitrogen, phosphorus, bacteria, and viruses to ground water.
- May be source of other contaminants: e.g., household hazardous wastes.

Agricultural/Silviculture Sources:
- May be source of contamination to both surface and ground waters
- Important contamination source in rural areas
- Can be controlled through use of Best Management Practices (BMPs).

Turfgrass Fertilizers (Lawn and Golf Courses):
- Slow vs. fast release fertilizers
- Integrated pest management programs

Feedlots and Manure
- Significant sources of nitrogen and phosphorus

Roadways and Paved Surfaces
- Roads, driveways, parking lots
- Sources of nitrogen, phosphorus, metals, oils and grease, salts, and VOCs
- Can affect surface and ground water quality.

Precipitation/Deposition
- Contribute significant amounts of nutrients to surface and ground waters.

6. ASSESSING WATERSHED IMPACTS ON WATER QUALITY

a. Solute Transport Modeling

- Analytical models
- Computerized numerical models

b. Nutrient/Contaminant Loading Analyses

- Developable Lot Buildout Analysis

  Determines the final number and type of development permitted under current zoning regulations;

  Assumes all developable land will be developed.

  Serves as an input to the nutrient loading analyses.

- Nitrogen/Phosphorus Loading Analysis

  Estimates the quantities from each potential contributor and overall final concentration in ground water.

- Mass Balance Approach

  Common approach to tracking contaminants through ecosystems.

Watershed Functions & Lake - Watershed Inter-Relationship

WATER AND THE HYDROLOGIC CYCLE

Understanding the interrelationships between lakes and their watersheds requires understanding the movement of water through soil and bedrock and over land surfaces. These are the primary routes of transport for water and associated pollutants through the lake ecosystem.

Hydrologic cycle

Water movement through the lake ecosystem is described by the **hydrologic cycle**. Hydrologic cycles operate at local, regional and global levels. Figure 2.1 depicts the hydrologic cycle for a local situation: a lake and part of its watershed. As can be seen, gravity and the sun provide the greatest energy to move water through the cycle.

Water inputs to lakes include direct precipitation, overland flow, tributary flow, and ground water flow. Water outputs include evaporation, transpiration by plants, ground water outflow, and stream flow. Tributary and overland flows together describe all surface flows. Ground water flows into a lake from upgradient recharge areas.

Precipitation includes rain, snow and hail and averages approximately 44 inches per year in Massachusetts. Approximately one half of precipitation is recycled back to the atmosphere via evapo-transpiration (the combination of evaporation and plant transpiration). Depending upon the local geologic, soil, vegetative, and slope conditions, the remainder flows through the watershed as either overland flow, tributary flow or ground water flow. In watersheds comprised of permeable sand and gravel (glacial outwash deposits) most of the net precipitation infiltrates to the water table and moves as ground water. In watershed comprised of mixed sands, silts and clays (glacial tills) little of the net precipitation infiltrates and the majority runs off the land's surface as overland flow, eventually discharging to tributaries or directly to the lake.

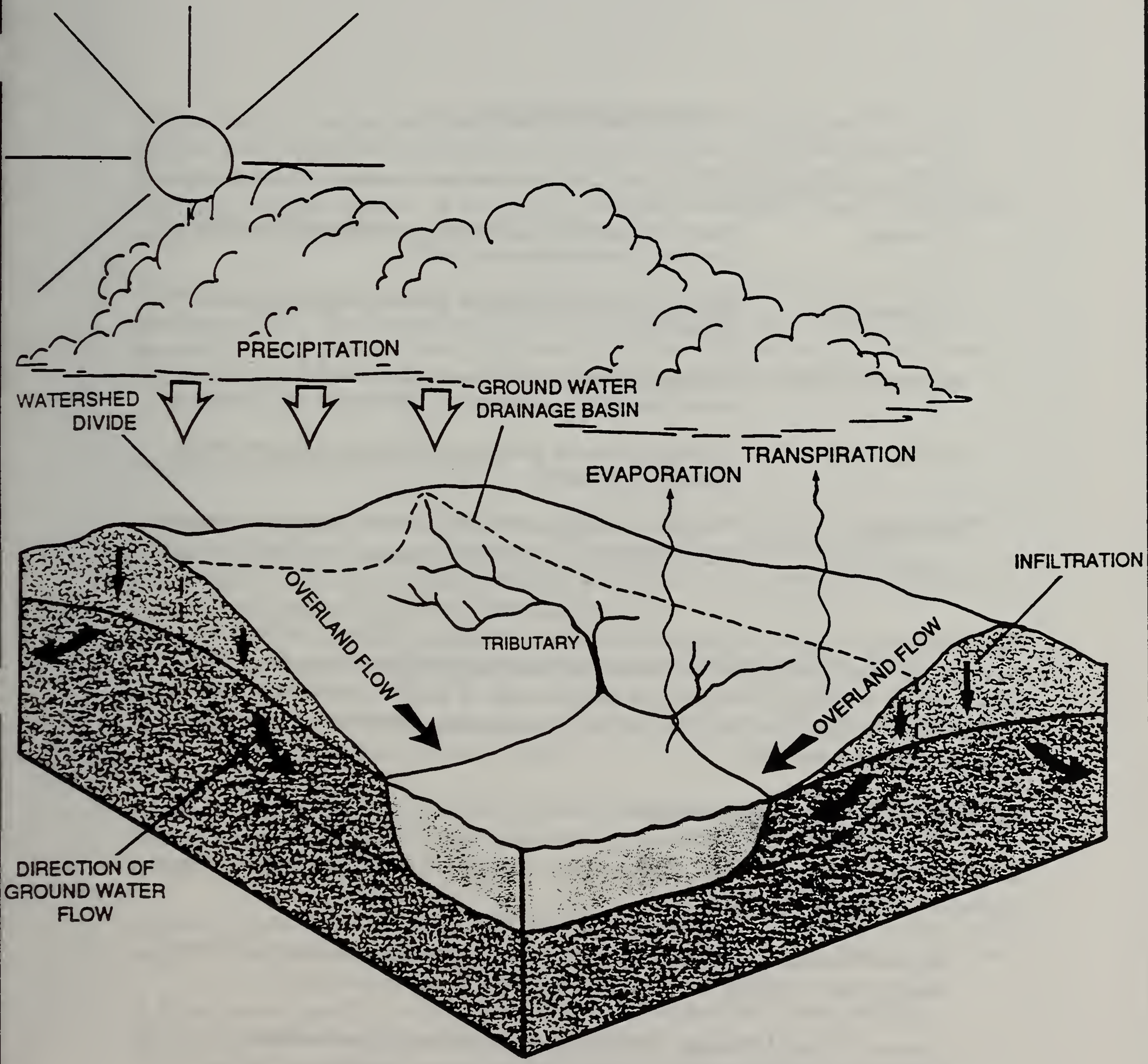

FIGURE 2.1
The Hydrologic Cycle

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KEY DEFINITIONS

Hydrology	The science of water. It describes the movement, distribution, chemistry, and occurrence of water.
Hydrogeology	The science of the interactions between water and geologic materials.
Hydrologic cycle	An abstraction of water's movement, in solid, liquid and gaseous states, through the atmosphere, lithosphere and biosphere.
Transpiration	Uptake of water by plants which then give off water vapor through their leaves.
Watershed	The land area from which water drains into lake (or stream).

The hydrologic cycle is an important concept because it clearly defines all avenues by which water can enter and leave a lake and its watershed. It allows us to determine the relative importance of each avenue and then to evaluate the impacts to the lake and its surrounding watershed resulting from a particular activity.

Watersheds & Hydrologic Budgets

A **Watershed** is the land area from which water drains into a lake (or stream). It consists of two components:

> Surface Drainage Basin is the land area from which all surface water flows drain towards a lake or stream at a lower elevation;
>
> Ground Water Drainage Basin is the land area and associated subsurface through which ground water drains to a lake or stream at a lower elevation.

A lake and its watershed form a lake system. When studying a lake system it is important to distinguish between the surface drainage basin and the ground water drainage basin, each of which have their own hydrologic functions. The characteristics of a lake's surface drainage basin, together with its ground water drainage basin, are a necessary input to analyzing the lake system's hydrologic budget and pollutant--contaminant loading.

A **Hydrologic Budget** provides an understanding of the components and relative magnitudes of hydrologic inputs and outputs to a lake system. It quantifies the amounts of water moving through the hydrologic cycle for a particular area or system. A hydrologic budget is necessary before evaluating nutrient pollutant loadings to a lake system.

Table 2.1 shows an example annual hydrologic budget for John's Pond in Mashpee, MA. The magnitude of the relevant inputs and outputs are presented. The greatest part of inflow to the lake comes from ground water inflows, while most of the outflow leaves the pond through stream flow.

SURFACE DRAINAGE BASINS

Surface Drainage Basin is the land area from which all surface water drains to a lake or stream at a lower elevation. Delineating watershed divide boundaries is usually a straightforward exercise. Use a topographic map with an appropriate scale and the following two rules:

1. Draw divide boundaries perpendicular to contour lines.
2. Draw divide boundaries through the center of contour saddles and closed contour loops.

When trying to determine flow direction for valley contours (which are V-shaped) remember water flows from the base to the wide opening of the contour V's.

Figure 2.2 presents the watershed divide boundaries for a small Massachusetts lake. All of the area within the solid line contributes surface flow to the lake.

A lake's water quality is directly related to its watershed characteristics. Important watershed characteristics include:

- Area: size in square miles, kilometers or similar units categorized as open water or land.
- Soil types and erodibility: critical for determining appropriate land uses and erosion control.
- Types and extent of vegetative cover: input to estimating runoff and evapo-transpiration.

TABLE 2.1

Hydrologic Budget for John's Pond, Mashpee, Massachusetts

	VOLUME (meters^3)	
	May 1978- April 1979	September 1979-August 1980
John's Pond		
Inputs		
Precipitation	1.7×10^6	1.2×10^6
Moody Pond Inlet (stream inflow)	0.4×10^6	0.2×10^6
Other Watershed Areas (groundwater inflow)		
Maximum	7.5×10^6	4.1×10^6
Minimum	3.4×10^6	1.8×10^6
Total Inputs (Maximum)	9.6×10^6	5.5×10^6
Total Inputs (Minimum)	5.5×10^6	3.2×10^6
Outputs		
Evaporation	0.8×10^6	0.8×10^6
Bog Use (includes transportation)	0.4×10^6	0.4×10^6
Natural Streamflow and Groundwater		
Seepage* - Maximum	8.4×10^6	4.3×10^6
-Minimum	4.3×10^6	2.0×10^6

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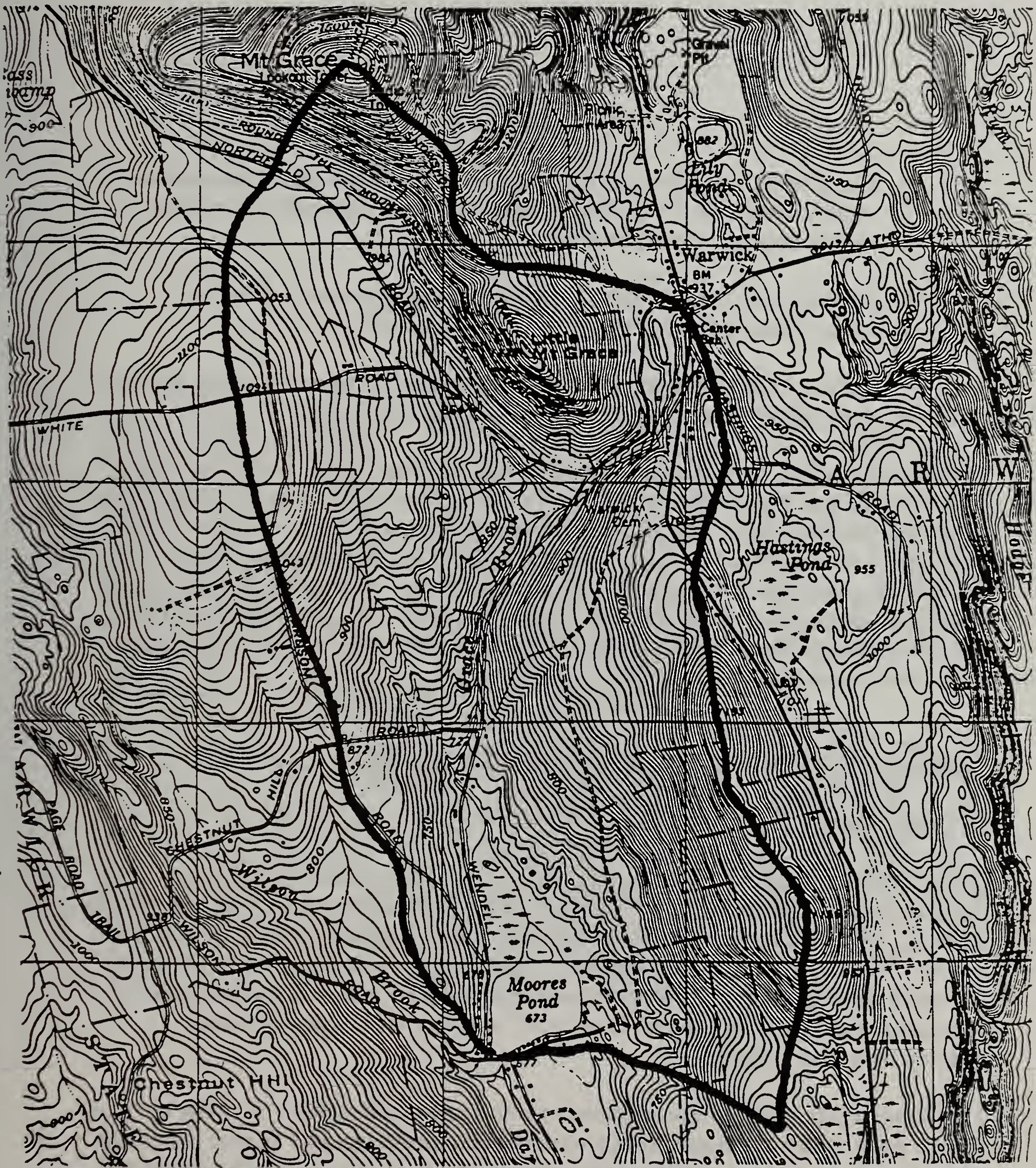
* Natural Streamflow and Groundwater Seepage is the remaining volume after subtracting Evaporation and Bog Use from Total Inputs

Source: Massachusetts DEP, 1982



Warwick, Massachusetts

FIGURE 2.2. Moores Pond Locus Drainage Basin

Source: Mt. Grace Quadrangle (USGS, 1977)

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- Land uses: categorization as agricultural, industrial, commercial, conservation, and residential uses critical to assessing potential water quality impact problems.

- Average and maximum slope: input to estimating time of concentration and erosion potential.

- Time of concentration: the time for a rain or water drop to travel from the furthest end of the watershed to the lake.

The number, type, size, and relative location of other water bodies draining into the lake are important inputs to evaluating the lake system. Each of the smaller lakes may have very different surface drainage basin characteristics. One lake's drainage basin may consist primarily of conservation land, while another is mainly put to agricultural uses while yet another watershed may have been developed primarily for residential land use. Each of these lake - surface drainage basin sub-systems contribute differently to the large lake's water and aesthetic quality.

GROUND WATER AND GROUND WATER DRAINAGE BASINS

Ground Water

Ground water is water which saturates pore spaces between gravel, silt, sand, or clay particles or in bedrock fractures in the subsurface environment (Figure 2.3). The subsurface environment is comprised of unsaturated and saturated zones. The unsaturated zone typically contains water film in the soil pores (in hydrogeologic terms, the pore water pressure is less than zero). The saturated zone's soil pores are filled with water, (pore water pressure is greater than than zero).

The **water table** divides the unsaturated and saturated zones. It is the surface where pore water pressure equals atmospheric pressure and is also called the potentiometric surface. Water table elevations fluctuate, typically reaching seasonal highs in the spring months and lows in the fall. This is due to the higher rainfalls and recharge during the spring, and higher evapotranspiration rates during the summer growing season.

A perched water table is a layer of saturated soil overlying a low permeability layer located above the main water table. Perched water tables can be seasonal in duration and may be the source of seasonal hillside springs or seeps.

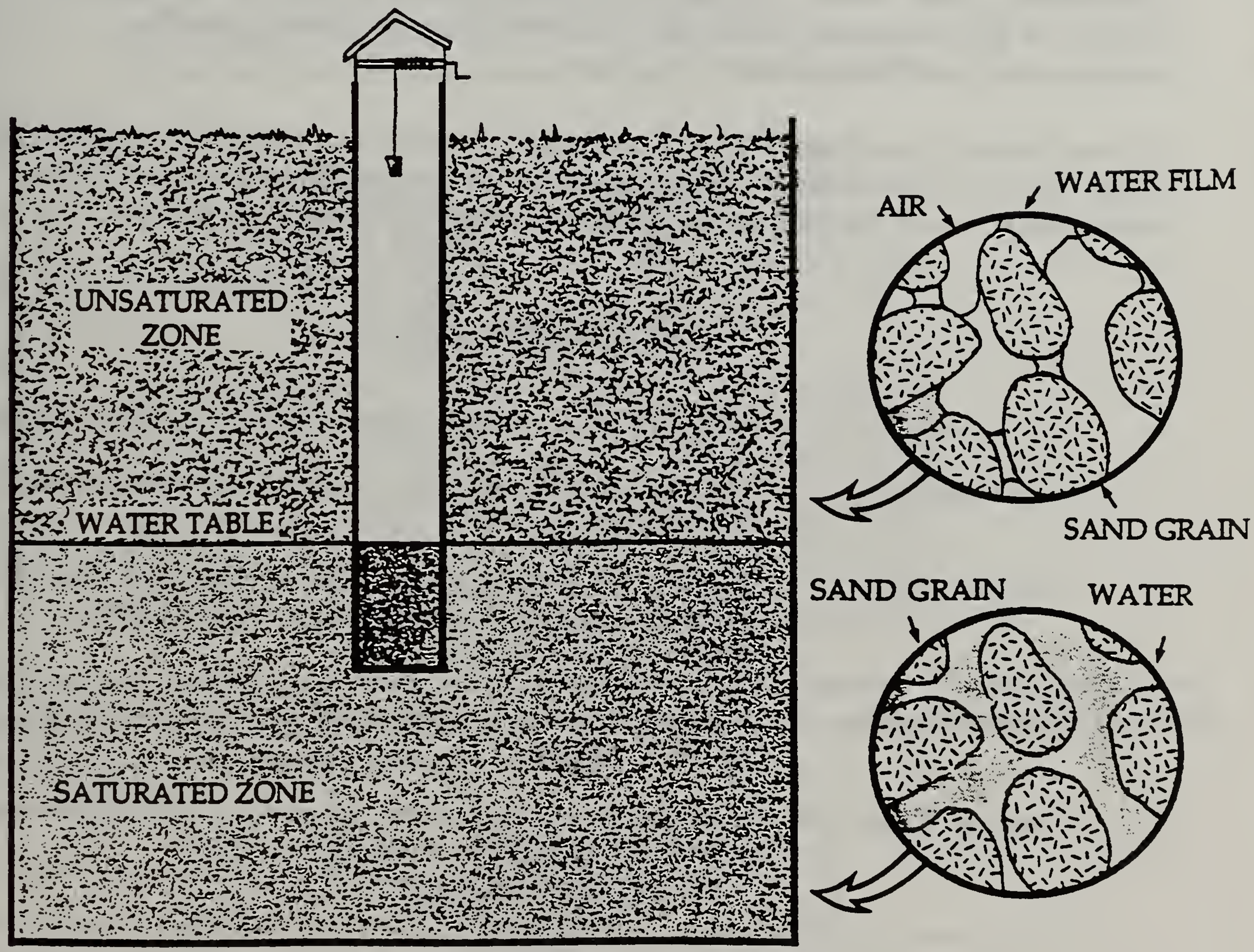

FIGURE 2.3
Idealized Cross Section of Subsurface

Source: Adapted from Strahler 1972

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Ground water is derived primarily from precipitation, which percolates (or infiltrates) downward and recharges the aquifer. Other ground water sources include infiltration from "losing" lakes or streams (see Figure 2.4). Depending upon local conditions, 10-50 percent of annual precipitation results in ground water recharge. The remainder is lost to runoff, evaporation and transpiration by plants.

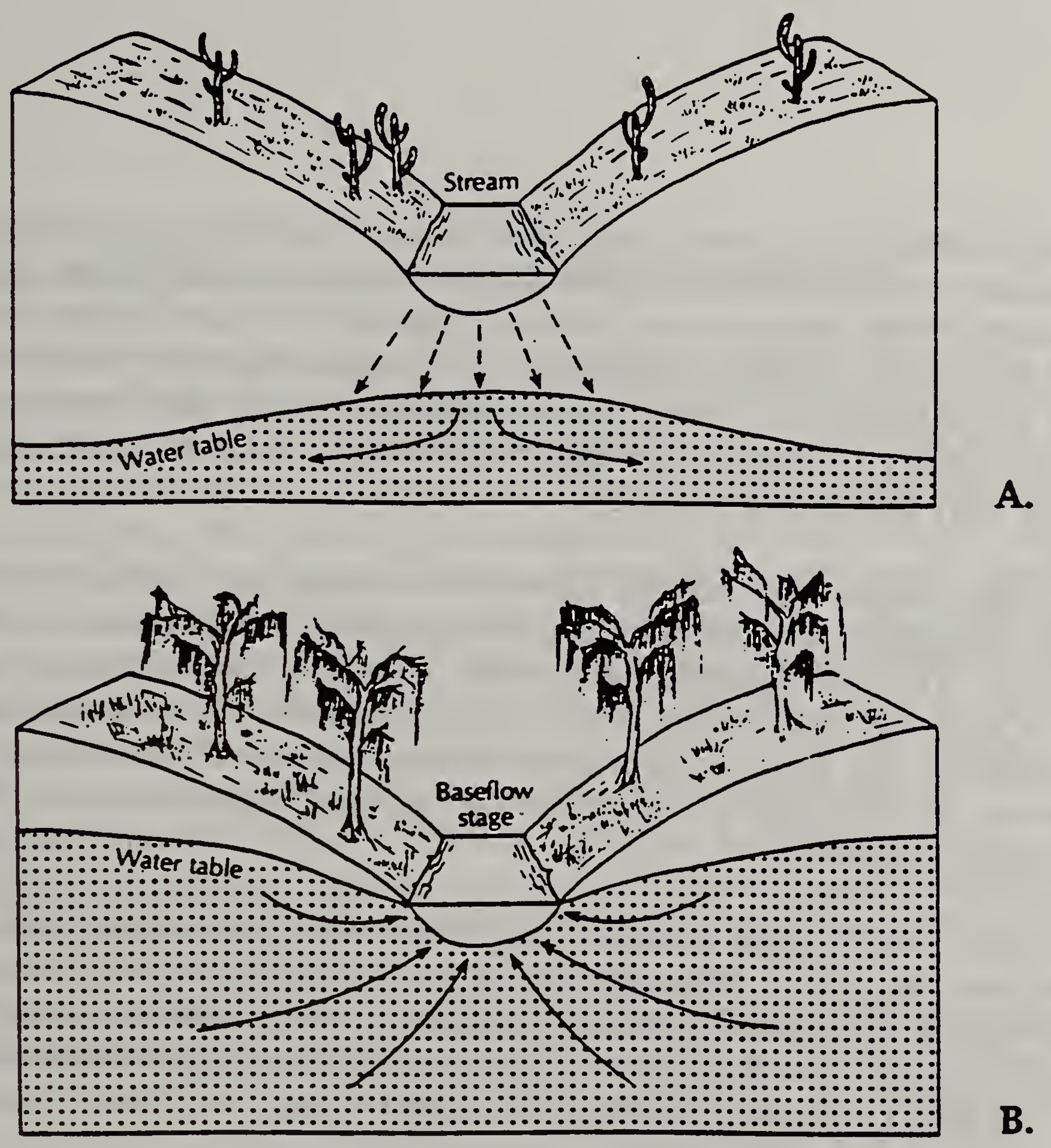
Ground water quality may be influenced by the types of geologic deposits that make up the watersheds. Common water quality problems include high concentrations of iron minerals, sulfur, mineral hardness, or acidity.

KEY DEFINITIONS

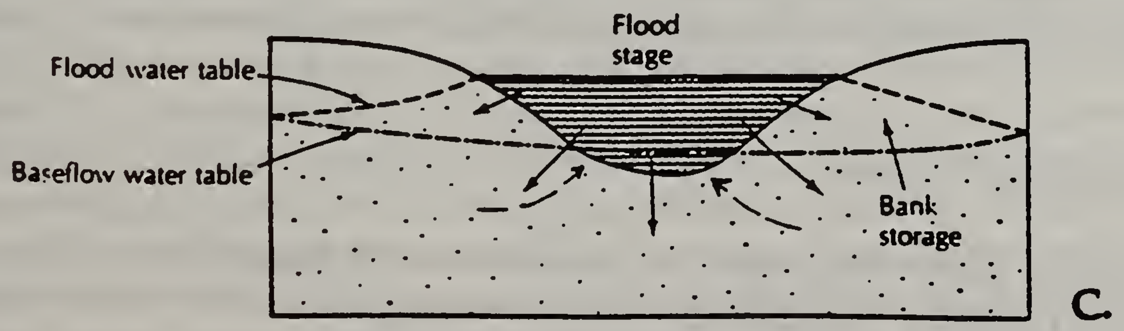
Hydrogeology	The science of the interactions between water and geologic materials and activities.
Water Table	Found in the upper elevation of the saturated zone, it divides the unsaturated and saturated zones. Also called the potentiometric surface.
Confined Aquifer	Have impermeable confining layers above and below the aquifer materials.
Perched Water Table	is a layer of saturated soil formed on a low permeability layer located above the main water table.

The ability of a geologic material's ability to hold or transmit water is described by two characteristics. Porosity is a measure of the void volume within a geologic material. The void volume is the amount of air or water-filled voids within a unit volume of material. The second characteristic, permeability, is a measure of a geologic material's ability to transmit water when a pressure or elevation difference is applied to the material.

A highly porous material is not necessarily permeable. Clays, which contain large volumes of void space (between 40 to 70%), are usually very impermeable because the voids are not directly interconnected.



A. Cross section of a losing stream, which is typical of arid regions, where streams can recharge ground water. B. Cross section of a gaining stream, which is typical of humid regions, where ground water recharges streams.



C. A stream that is gaining during low-flow periods (solid arrows) can temporarily become a losing stream during flood stage (dashed arrows).

FIGURE 2.4
Losing and Gaining Surface Water Bodies

Source: Fetter 1988

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The geologic formations which hold and transmit sufficient quantities of ground water to permit economic development are called aquifers. In Massachusetts these deposits are commonly glacial outwash deposits which consist of well sorted sands and gravels. Hydrogeologists and water supply engineers are interested in knowing the location of high yield aquifers when siting water supply or wastewater disposal systems. In some instances, lake watersheds may function as aquifers.

Ground water moves from higher water table elevations to lower water table elevations, ultimately discharging to downgradient streams, lakes, wetlands or the ocean. The development of a water table map from measurements made on a series of observation wells enables determination of ground water flow directions. The water table map is an important tool in delineating a ground water recharge area. Ground water moves perpendicular to the water table elevation contours.

Ground water flow is three dimensional. Downward flow usually occurs at the higher elevations of a recharge area while upwelling usually occurs at the lower elevations of a recharge area. Upwelling into a lake or stream bottom, as shown in Figure 2.4b, is caused by pressure and elevation differences between the lake or stream bottom and ground water.

Ground water flow velocities are generally much slower than surface water velocities. They typically range between several feet per day (in sands and gravels) to several feet per year (in finer materials such as silts and clays). However, ground water can travel faster through faults and fractures in bedrock formations, sometimes reaching rates similar to surface water velocities.

Ground Water Drainage Basins

To gain a meaningful understanding of a ground water drainage basin, one must start with the geology. The geology of the drainage basin can be divided into two major components: bedrock and surficial deposits.

Bedrock is the solid rock of the earth's crust. The areas where bedrock is visible at the land's surface are known as outcrops.

Bedrock is commonly overlain by surficial deposits of **unconsolidated sediments.** These sediments range from cobbles and gravel to sands to finer silts and clays. In Massachusetts, most surficial deposits are of glacial origin and were transported and deposited by glaciers or by meltwater streams associated with them.

Sources of Existing Information Hydrogeologic Investigations

Large amounts of hydrogeologic and geologic information have been compiled by the United States Geological Survey (USGS) and are useful to in lake management. Bedrock and surficial geologic quadrant maps exist for nearly all of Massachusetts. They can be found in many university libraries or are available from the USGS. Hydrologic Investigation Atlases, which describe the availability of ground water, stream flows, estimated depth to bedrock, etc., are available for large parts of the state. The USGS also has produced Geophysical Investigation Maps, Hydrologic Data Reports (which contain information on stream and river flows), miscellaneous maps, Open-File Reports, Water Resources Investigations, and Professional Papers produced by consulting firms. The Massachusetts Department of Environmental Protection (MA DEP) has compiled a Massachusetts Hydrogeologic Information Matrix that lists all available USGS reports for any Massachusetts town or city. It is available from the state bookstore in Boston.

Geologic references and USGS reports provide a regional level geologic information and analyses. However, accurate delineations of the ground water drainage basin may require more site specific data. Hydrogeologic investigations may include a combination of geophysical and drilling techniques.

Geophysical Investigations

Geophysical techniques include electrical resistivity, seismic refraction and ground penetrating radar. Electrical resistivity--conductivity soundings are useful in locating high yield bedrock or unconsolidated sediment aquifers. Seismic refraction methods are often used to determine the thickness of unconsolidated materials overlying bedrock. Seismic reflection methods can provide information about depth to bedrock, slope of the bedrock and depth to the water table. Magnetometer and ground-penetrating radar surveys can help locate buried objects, waste disposal sites and interfaces between different geologic formations. Ground-penetrating radar surveys can also be used to map water table elevations.

Drilling Methods

A variety of drilling methods exist: hollow stem auger, cable tool, and air and mud rotary. In Massachusetts, most surficial deposit borings are generally more efficiently drilled with a hollow stem auger rig. Soil samples are collected within the auger by driving a split spoon sampler (or other sampling device) through the hollow core into the sediments below. The hollow stem auger cannot bore through bedrock, may be stopped by boulders and has a limited operational depth. Its primary advantages are its relative low cost and portability and because it does not greatly disturb in-situ sediments, allowing for more accurate measurement of hydrogeologic properties.

In contrast, air and mud rotary drills often alter the physical and chemical properties of the soil-borehole interface by coating the interface with drilling muds. The rotary drill method utilizes a heavy rotating bit that is constantly flushed by pressurized air, water or prepared "muds". Rotary rigs are usually large and heavy but fast which enables them to drill to great depths (thousands of feet). Because of their weight and size, they are restricted to fairly level, hard-packed sites. They are often used to drill bedrock water supply wells and are more commonly found than cable tool rigs, which have much slower drilling rates.

In sandy or silty soil areas without cobbles or stones, boreholes can often be drilled with hand augers. Though limited to shallow depths (approximately 20 feet) and softer soil types, hand augers are much less expensive than drilling rigs and, when operated by a skilled driller, provide a continuous record of sediment types and perfectly adequate boreholes.

Wells and Piezometers

Wells and piezometers are very similar in both form and function (see Figure 2.5). Both consist of riser pipes and well screen, and allow for measurement of water table elevations.

Piezometers, which usually have narrow diameter screens and risers, are not designed to be pumped. Simpler to install, they are generally used to measure water table elevations. Piezometers placed on lake shores or stream banks are particularly well suited to measuring ground water seepage into and out of the water body.

Wells serve a greater variety of purposes than piezometers: water supply, water table level monitoring, water quality monitoring, and waste or recharge injection. The well (or piezometer) is connected to the underlying ground water through the well screen, which is a slotted pipe. A sand or gravel pack may be placed between the screen and the geologic materials to help reduce inflow of fine particles. The well is sealed above the well screen with cement grout or bentonite clay to prevent contaminated surface water from percolating directly into the well. The riser pipe is usually capped with a protective casing to prevent damage and inadvertent well contamination.

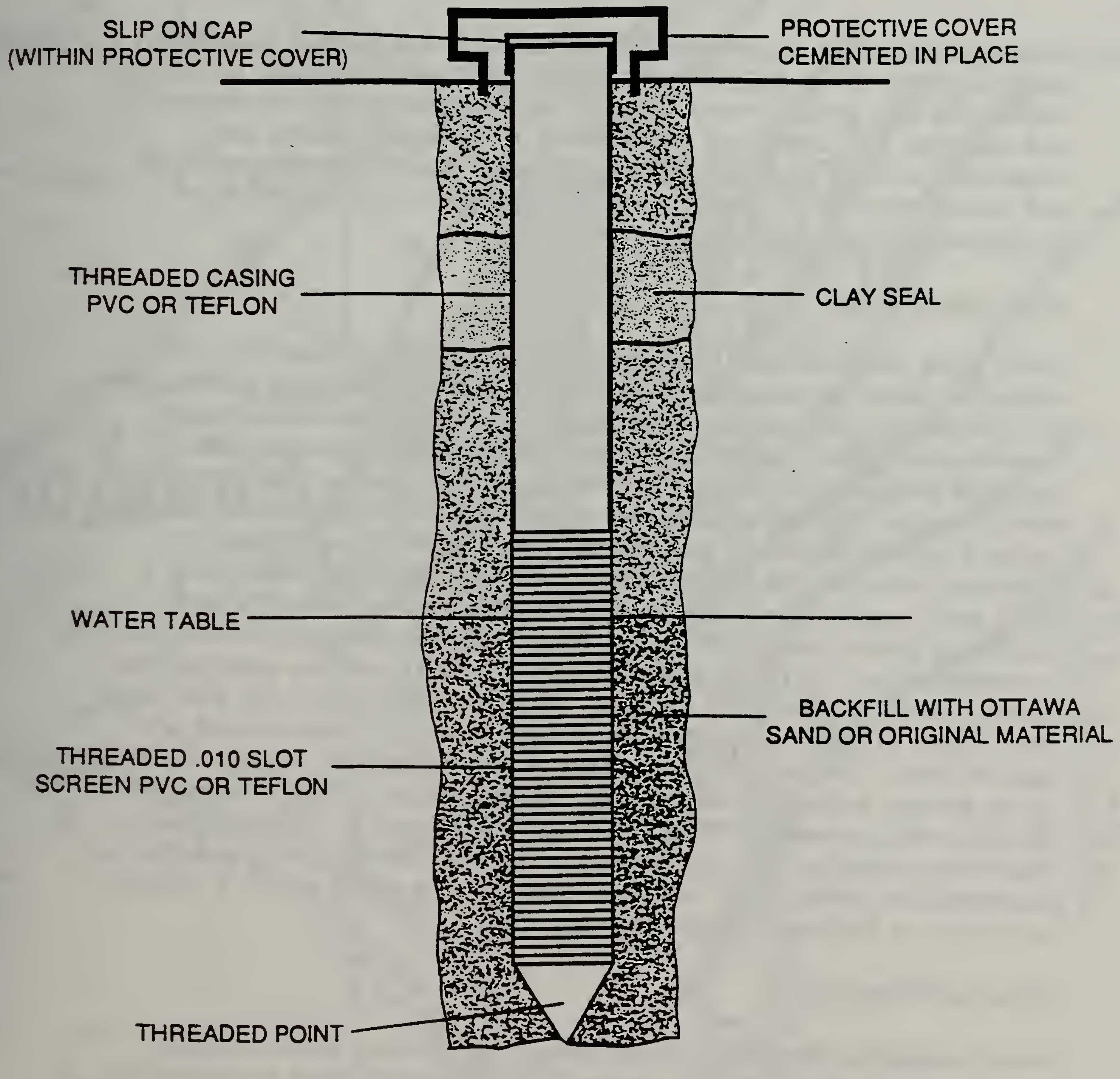

FIGURE 2.5
General Monitoring Well - Piezometer Construction

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Although care must be taken when selecting well construction materials (stainless steel, teflon, etc.) for water supply and hazardous waste monitoring wells, most lake ground water drainage basin investigations will require two inch diameter PVC risers and well screens. Proper design, siting and installation of wells is crucial to collecting good quality hydrogeologic data and should only be undertaken with the supervision of an experienced hydrogeologist and driller.

Flow Net Analysis

Water level measurements from installed wells and piezometers can be utilized to construct water table and flow net diagrams showing ground water flow directions. To construct these maps, water table measurements are recorded from wells installed in an area. Areas with equal water table elevation are connected and are referred to as equipotential lines, or water table contours. Ground water flows at right angles to equipotential lines from higher to lower elevations. A water table map shows the direction of horizontal ground water flow in map view. Figure 2.6 is an example of a water table map. A flow net map presents the direction of vertical and horizontal ground water flow. Additional well measurements are necessary to prepare a flow net map. This is done by drafting flow lines perpendicular downgradient to water table contours. Ground water flows along these lines from higher to lower water table elevations. Figure 2.7 is an example of a flow net map. The ground water recharge map (Figure 2.8) presents the area where ground water flow contributes to a lake or pond. This information coupled with permeability data allows the investigator to compute ground water flow velocities and discharge rates. In this manner the investigator can determine the amount of ground water discharging into a lake and the size and extent of the ground water drainage area.

Types of Watersheds

After completing evaluations of the surface and ground water drainage basins, a lake manager should review the hydrologic budgets to determine whether the lake system in question is dominated by surface water inputs, ground water inputs, or a mix of the two. This determination will assist the lake manager in efficiently focusing management resources on the most critical water inputs.

A surface water dominated lake receives the greatest part of its water inputs from surface water flows when compared to ground water or precipitation inputs. This lake system has at least one surface water inlet and one outlet. An example is Richmond Pond. A hydrologic budget for the lake is shown in

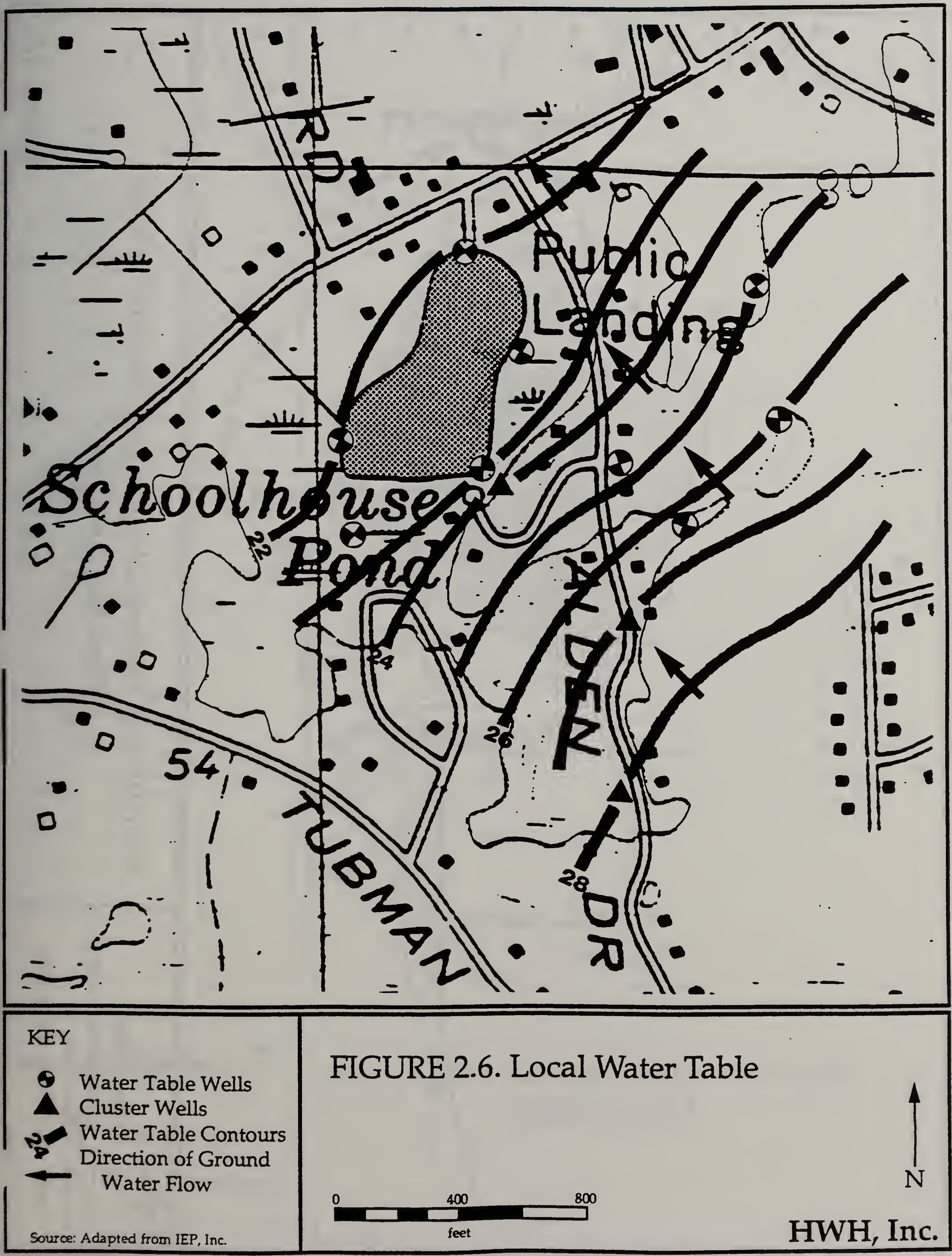

FIGURE 2.6. Local Water Table

Source: Adapted from IEP, Inc.

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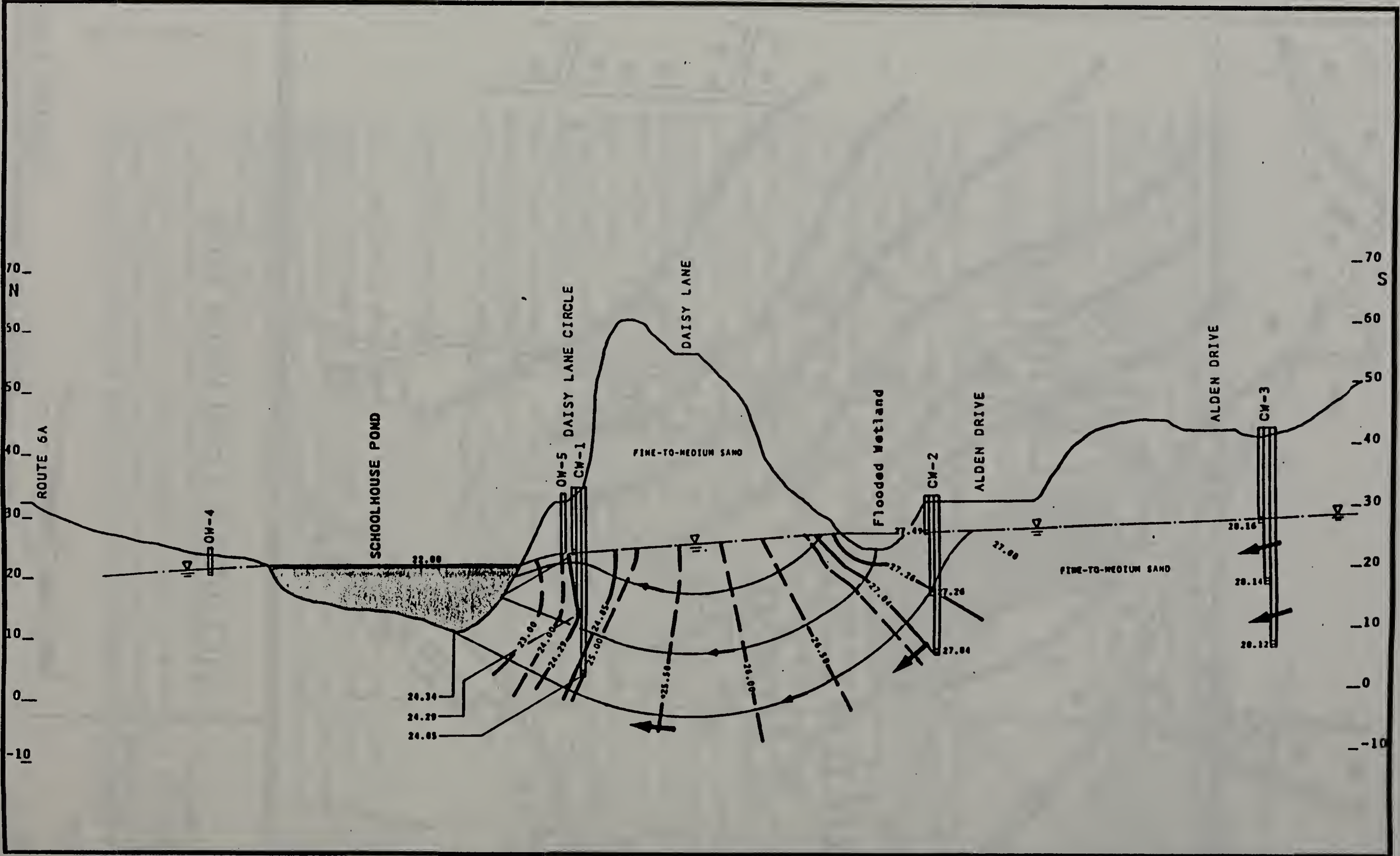

LEGEND

— · —	Water Table
— —	Equipotential Lines
—◄—	Flow Lines
◄	Ground Water Flow

Source: [illegible] 1987

FIGURE 2.7. Hydrogeologic Cross Section Showing Flow Net Analysis

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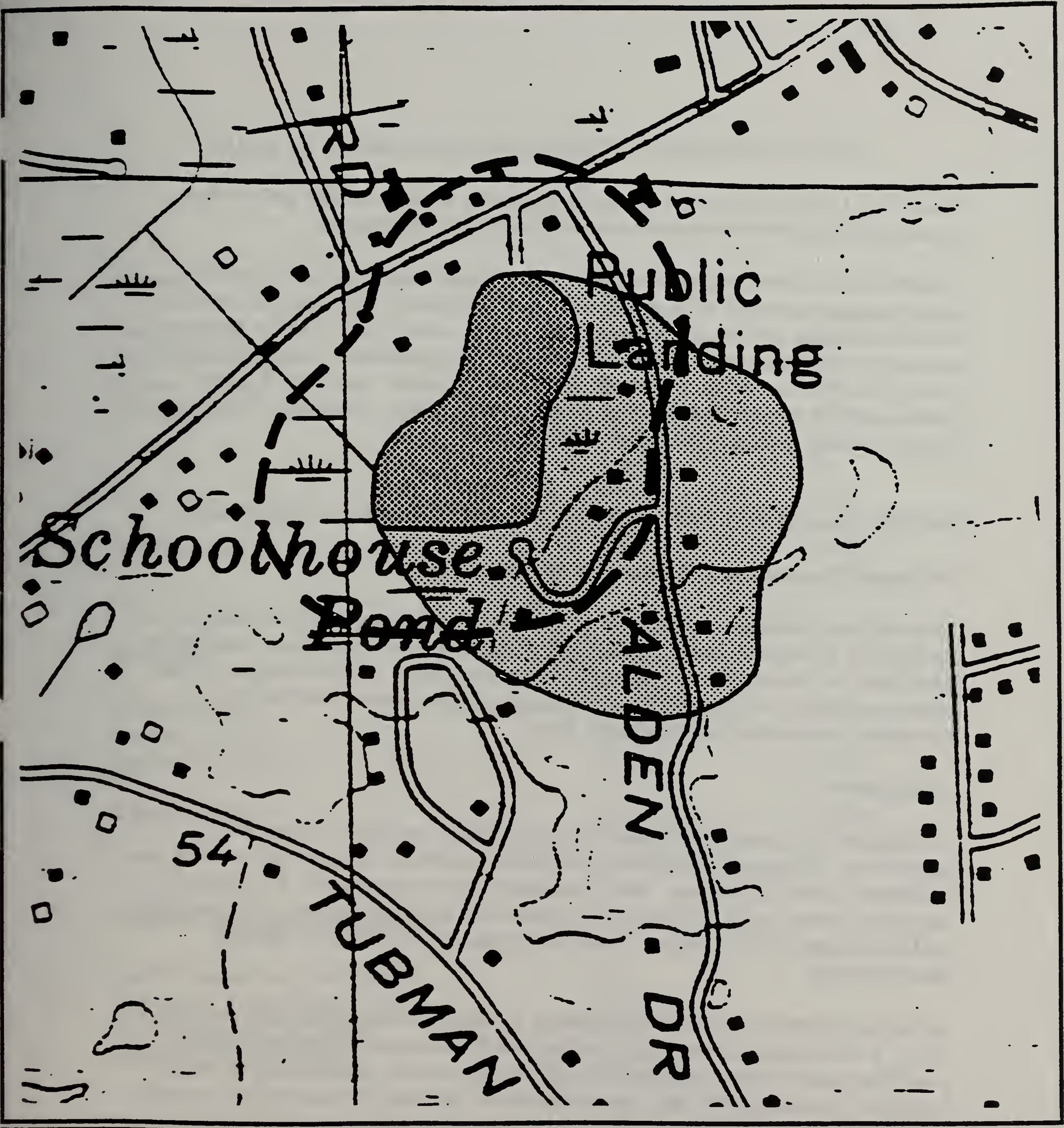

FIGURE 2.8. Ground Water Recharge Area to Pond

Source: IEP, Inc.

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Table 2.2. Lakes of this type are most amenable to both in-lake and surface water drainage basin management techniques (see Section 4).

Lakes which receive the greatest part of their hydrologic input via ground water seepage are said to be **ground water dominated**. They may or may not have tributaries and outlet streams. An example is John's Pond in Mashpee in eastern Massachusetts. Table 2.1 presents the hydrologic budget for John's Pond. Many lakes in the eastern half of Massachusetts are ground water dominated. A typical drainage area to a ground water dominated lake in a bedrock valley aquifer is shown in Figure 2.9.

WATER QUALITY AND WATERSHED-LAKE INTERRELATIONSHIPS

Pollutant/Contaminant Transport and Attenuation

The fate and transport of pollutants through a watershed are controlled by a number of important biological, physical and chemical processes which take place both in the surface water and the ground water environments. These processes must be understood by the lake manager when developing a successful watershed management plan.

Adsorption

Adsorption is a physical-chemical process which reversibly binds two substances. The most important adsorption processes occur at soil - water and sediment- water interfaces. Soils and sediments often contain a significant organic fraction, with which many metals and organic compounds (pesticides and herbicides, VOCs, hydrocarbons, etc.) readily bind and are thereby immobilized.

Adsorbed substances can remain bound to their substrates for long periods of time. Phosphorus, metals (such as lead, cadmium and copper) and many pesticides and related compounds will remain bound indefinitely to soil or sediment particles until they are transformed by other processes, for example, biological assimilation.

TABLE 2.2 HYDROLOGIC BUDGET FOR RICHMOND POND

Inputs	Station	Cu. M/Min	% of Total
Precipitation		1.74	4.0
Ground Water		0.23	0.5
Direct Runoff		0.32	0.7
Tributaries	RP-1	26.30	59.8
	RP-2	11.50	26.1
	RP-3	2.60	5.9
	RP-3A	1.30	3.0
Total Inflow		43.99	100.0
Outputs:			
Evaporation		1.13	2.6
Ground Water		0.4	0.1
Surface Outflow	RP-5	42.82	97.3
Total Outflow		43.99	100.00

Other Hydrologic Features

Mean Detention Time (Days)	48
Detention Time Range (Days)	14-122
Flushing Rate (Per Year)	7.7
Response Time (Years)	0.20-0.33

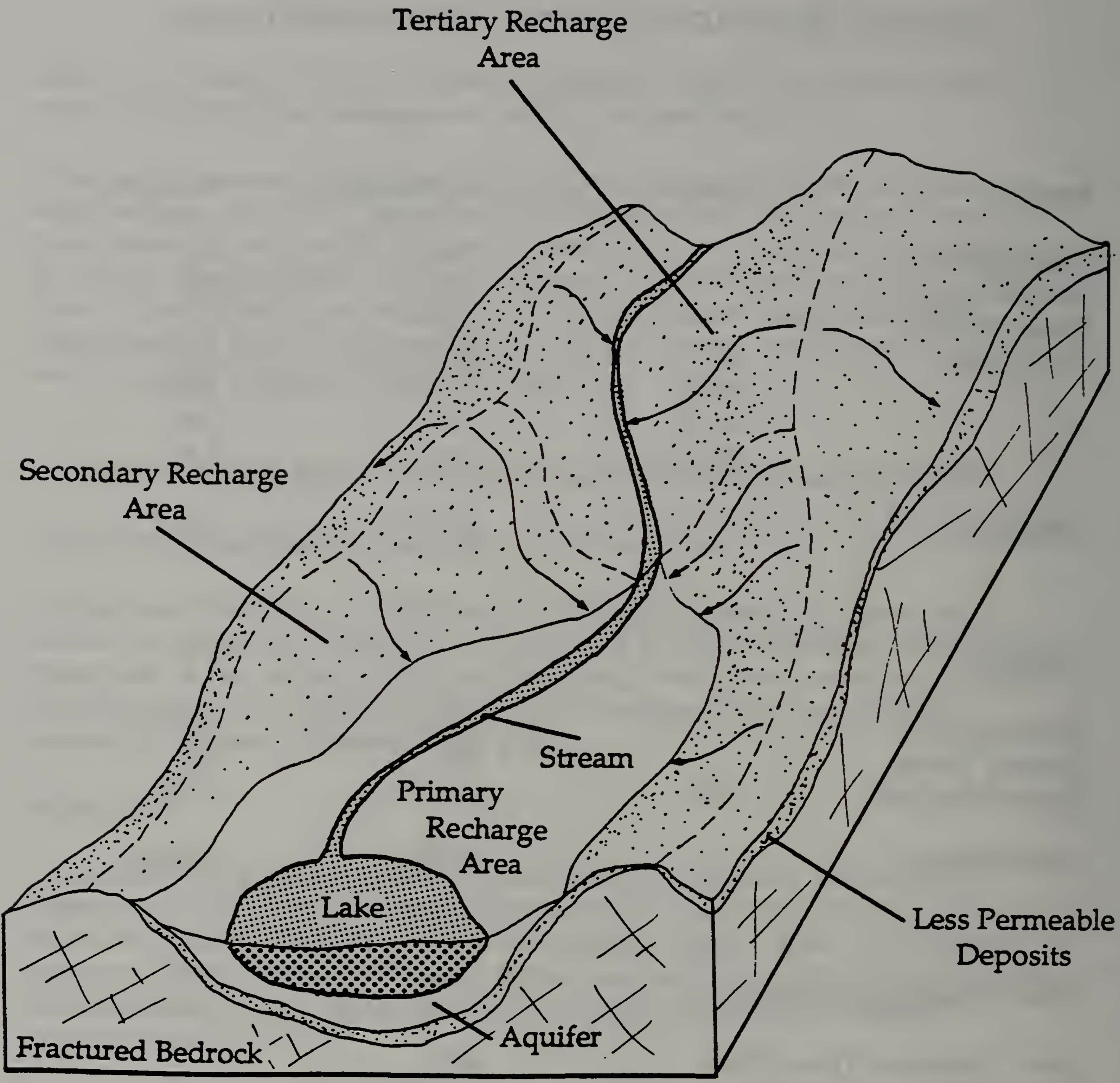

FIGURE 2.9
Recharge Areas to Groundwater Dominated Lake

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Dissolved Transport

Most pollutants are water soluble to some degree; that is, they chemically dissolve into water. This is a major mode of pollutant transport, especially for nutrients (nitrogen, phosphorus), iron and related minerals, various metals, salts, and gases.

Some contaminants have very low solubilities: PCBs, many pesticides and herbicides, and complex organic compounds. The major transport mechanism for these contaminants is the physical transport of the suspended particles to which they have been adsorbed.

Phosphorus is transported through the watershed in both dissolved and particulate forms. Under anoxic conditions (such as downgradient of a septic system or in lake bottom sediments) phosphorus dissolves and becomes mobile. Where oxygen is present phosphorus commonly oxidizes and forms a precipitate with iron or aluminum where they are present. Such phosphorus precipitates may be transported with surface runoff or through ground water.

Volatilization

Volatilization is a measure of a material's tendency to move from a liquid to gaseous phase. Volatile substances tend to evaporate more readily into the atmosphere than nonvolatile substances. Examples include volatile organic compounds (benzene, toluene, xylenes, formaldehyde, solvents, etc.). Volatilization can also occur in the subsurface environment, as evidenced by buried hazardous wastes escaping into the ground water and into the atmosphere after passing through the soil column as vapors.

Biological Assimilation

Biological assimilation is the process by which living organisms take in substances and incorporate them within their cells or related structures (hair, bark, horns, etc). It is one of the most important processes that directly affects living organisms, including humans.

Once the metal or other contaminant is assimilated within the organism, its retention period may vary from hours (alcohols) to years (cadmium) depending upon which organ or tissue systems are affected. In the case of plant assimilation of nutrients or metals, the substances may return to affect water quality immediately after die-off, such as occurs in the autumn.

Biological Transformation

Bacteria, fungi, protozoa, plants, and animals all take in a wide variety of chemical compounds and transform them through their metabolic processes into other chemical compounds. The most important biologically-mediated transformations affecting watershed water quality typically occur in the topsoil, in wetlands, and at sediment/soil--water interfaces because of the tremendous numbers of organisms living within these zones.

As described in Section 1, the nitrogen and phosphorus cycles are driven to a large part by microbial communities. For example, one set of bacterial species mediates the transformation of nitrogen from nitrate to nitrite forms while two sets of species mediate the transformation from nitrate (the most oxidized state) to nitrogen gas (see Figure 1.8 for description of nitrogen cycle). A clear understanding of the biological transformation processes operating within a lake system is essential to determining the impacts from different land uses or activities.

Sources of Contamination

Contamination in ground water and surface water comes from a wide range of sources. The contaminants include nutrients, volatile organic compounds, petroleum, hydrocarbons and heavy metals. The typical sources of contamination that affect lakes and ponds are described below with discussions on the types of contaminants associated with each source.

Septic Systems

Septic systems are comprised of a septic tank and a leaching facility (Figure 2.10). The septic tank provides for the settling out of solids and some biological treatment of the wastes. The leaching facility disposes of the liquid wastes into the subsurface environment. If tanks are not properly maintained (pumping once every three years is recommended for single family homes), solids may pass out of the tank and clog the leaching facility. This can cause hydraulic failure of the system resulting in the possible backing up of wastewaters into the building or effluent to break out onto the land surface. Where raw sewage breaks out onto the land's surface a direct route of transport to the lake exists.

Conventional septic systems provide minimal treatment of wastewater. Leaching facility effluents contain approximately 40 to 60 mg/l nitrogen and 8-38 mg/liter phosphorus (Hall, 1975). The effluents also contain large numbers of pathogenic bacteria and viruses. Virus inactivation times in

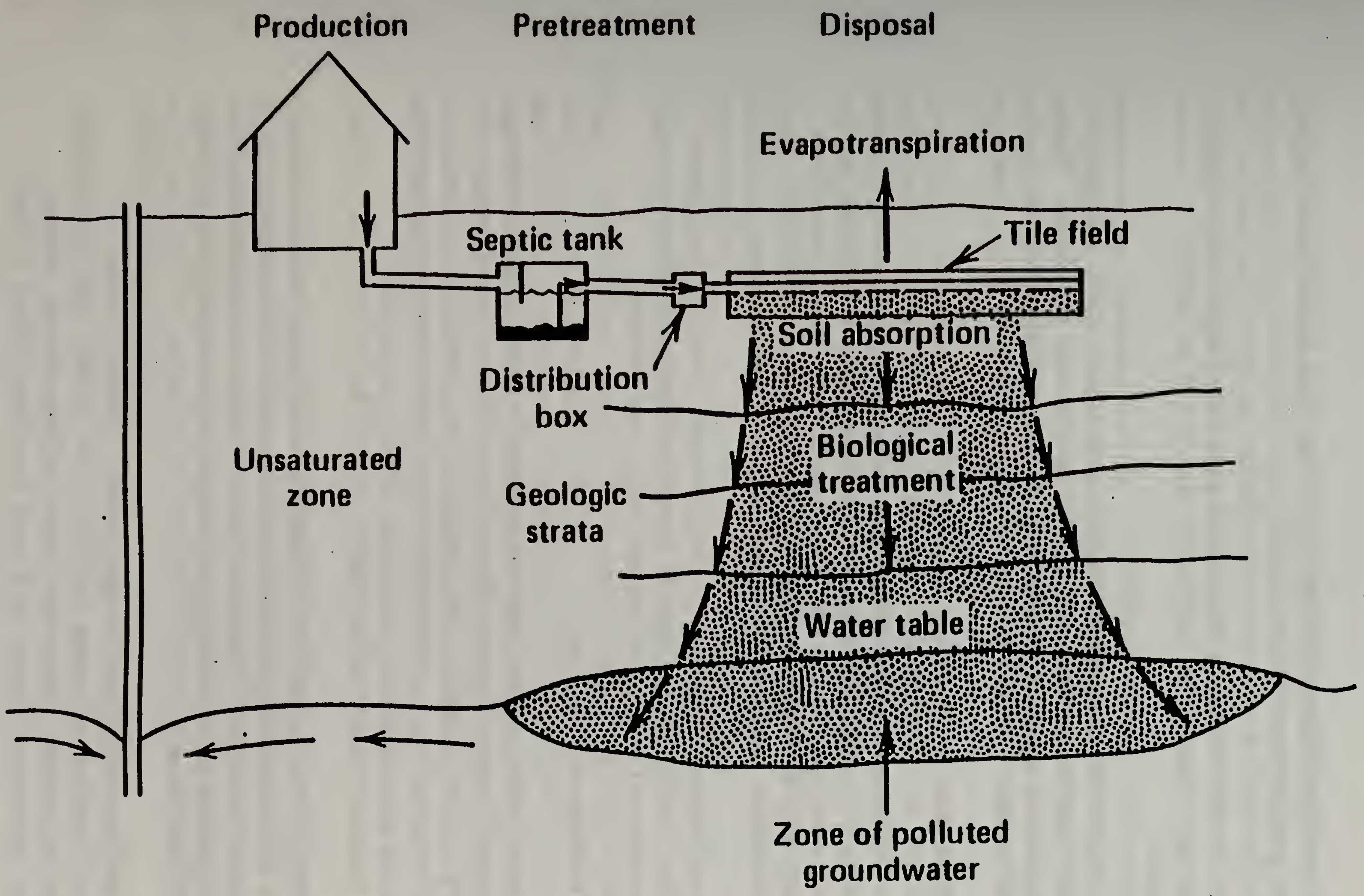

FIGURE 2.10
On-Site Septic System and Plume Generation

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ground water are approximately 120-200 days. They have been documented to move distances greater than 300 feet in soils.

Septic systems can also introduce hazardous wastes into the ground water if the owner uses septic cleaners or improperly disposes of household hazardous wastes.

The cumulative effects of many small septic systems on nutrient, pathogen or hazardous waste levels in downgradient waters can be very significant. These impacts are dependent upon septic system location and density relative to receiving water bodies.

Stormwater Overflows

Stormwater overflows and combined (sewage and stormwater) sewer overflows, normally found in heavily urbanized areas, are well known to have significant water quality impacts when overloaded. The Charles River Basin and Boston's Inner Harbor are perhaps the best known victims of stormwater--combined sewer overflow pollution in Massachusetts.

Stormwater overflows act as sources of a wide variety of surface and ground water pollutants: metals, volatile organic compounds, oils and grease, pathogenic bacteria and viruses, suspended solids, and nutrients.

Agricultural/Silvicultural Sources

Many agricultural and silvicultural practices present contamination threats to surface and ground waters, especially in rural areas. These threats include application of pesticides, herbicides and fertilizers. Any of these substances can be carried by runoff into surface waters or infiltration into ground waters. These sources are most effectively controlled through use of Best Management Practices (BMPs) as described in Section 4.

Fertilizers are applied to increase the availability of nitrogen, potassium and phosphorus to crops (including turfgrasses) and, as such, are important sources of nutrient pollution. Fertilizers have often been cited as the most important phosphorus sources leading to the cultural eutrophication of lakes and streams in rural areas.

A variety of fertilizers are utilized in agriculture. Generally, these compounds are classified into water soluble of "fast release" and "slow release fertilizers. The fast release compounds, which include calcium nitrate, sodium nitrate, ammonium sulfate, and urea, have been shown to leach quickly. Ureaformaldehyde, methylene urea, isobutylidene diurea, and sulfur-coated urea, which are examples of slow release fertilizers, are less prone to leaching. Fertilizer leaching is controlled by soil and hydrologic conditions. Fertilizers may be applied through irrigation systems, sprays or powders.

Herbicides and pesticides include a tremendous variety of chemicals utilized for the control of fungi, insects, arthropods, nematodes, and weeds. A great number of them are known to be lethal to many species of aquatic plants and animals. While application is usually restricted by law to licensed applicators, household use of these compounds can lead to adverse water quality impacts.

Chemical formulation, rate of application, timing of application, soil conditions, and hydrologic factors all affect the movement of pesticides and herbicides. Many of these compounds are not very water soluble, but are actively adsorbed to organic soil and sediment materials.

Feedlots and manure piles, common in many agricultural areas, can be significant sources of nitrogen and phosphorus pollution to surface and ground waters.

Roadways and Paved Surfaces

Roads, driveways and parking lots serve as sources of nitrogen, phosphorus, metals, oils and grease, salts, and VOCs. Runoff from paved areas has lower concentrations of dissolved nutrients than septic system or lawn fertilization sources. However, the total volume of runoff can be much greater than that of the other sources, making their contribution just as significant. Numerous studies have shown that metals (lead, copper and cadmium) loadings from paved surfaces are significant pollution sources.

Precipitation/Deposition

Precipitation and atmospheric deposition have been shown to contribute significant amounts of nutrients, particularly nitrogen to surface and ground waters. Atmospheric deposition of phosphorus directly to a lake surface can be a large component of the nutrient budget. For the Wequaquet Lake system on Cape Cod, 47.5 percent of the total phosphorus load is from atmospheric deposition (IEP, Inc., 1989).

Underground Storage Tanks

Petroleum products stored in underground storage systems poses one of the greatest threats to ground water quality in the US. The US Environmental Protection Agency estimates that approximately one third of all existing storage systems nationwide are currently leaking. The average expected lifespan of steel tanks in acidic soils (commonly found in Massachusetts) is approximately 15 years. At this point corrosion may result in many pin-hole sized leaks which can discharge hundreds of gallons of fuel over a several month period. These leakage rates are sufficiently small to pass unnoticed by the tank owner for many months, but are large enough to cause significant ground water contamination problems.

Leaking underground storage tanks can be significant sources of oil, fuel and volatile organic compound (VOC) contamination. Gasoline, for example, contains a variety of hazardous compounds, such as benzene, toluene and xylene. Benzene is a known human carcinogen.

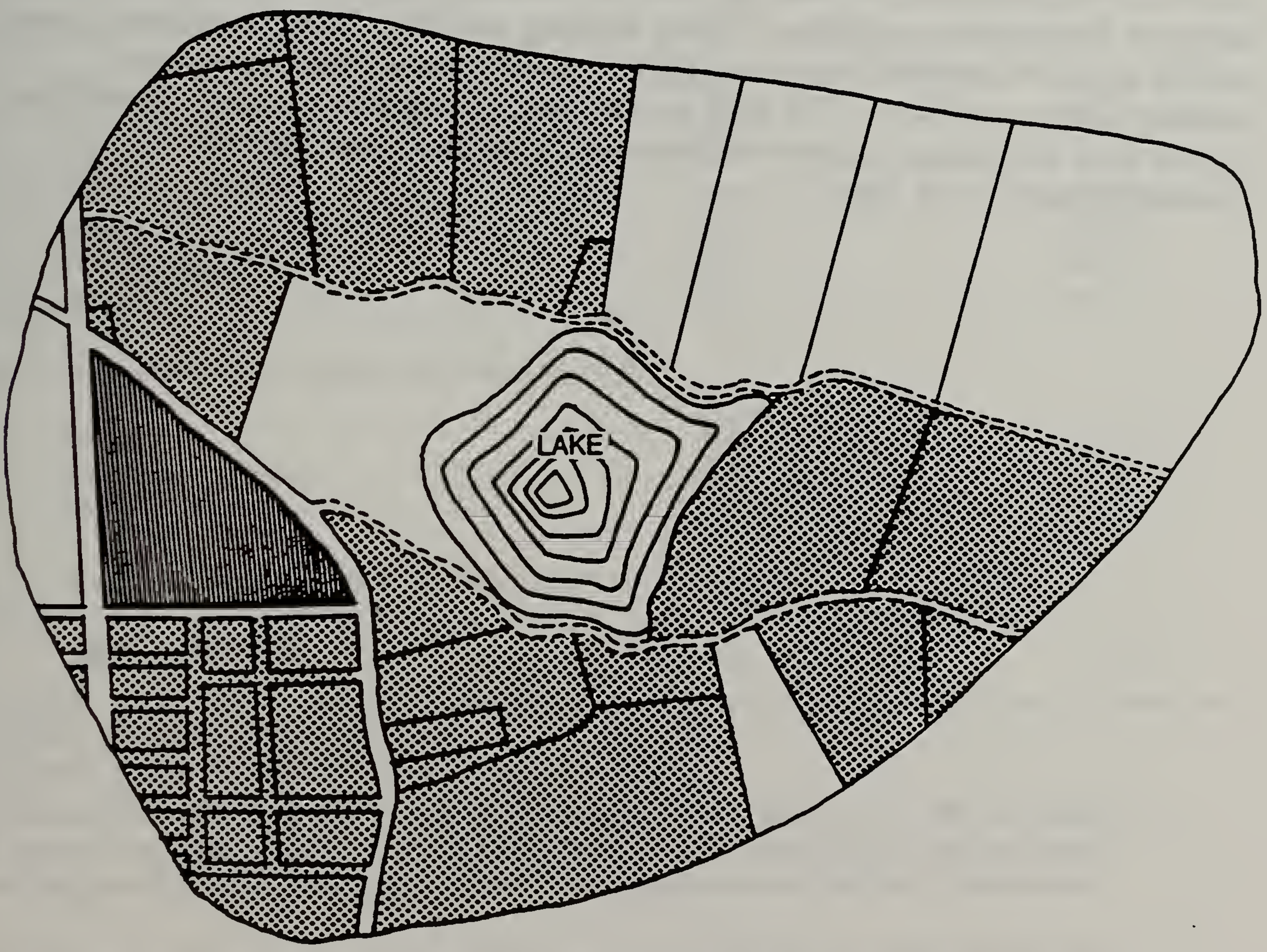
ASSESSING WATERSHED IMPACTS ON WATER QUALITY

Nutrient/Contaminant Loading Analyses

The first step in preparing for a watershed-wide nutrient or contaminant loading analysis is to gain an accurate understanding of the land uses within the watershed. The land use analysis should first determine the type, intensity and distribution of existing land uses. This is best accomplished by utilizing assessor's tax maps, aerial photographs and field checking.

This analysis can then be followed by determining the development potential of all vacant parcels within the lake system's watershed according to the existing zoning, subdivision and other land use codes. Wetlands, flood plain and soil limitations should also be considered. The total development potential of the watershed is determined by summing existing development and future potential development. This sum quantifies the "saturation" development or "build-out" population for the watershed. An illustration of this analysis is given in Figure 2.11. This quantification serves as a necessary input to the nutrient loading analyses.

Category	Acres	Units
Developed Land	31	95
Subdividable/Developable	337	219
Restricted Open Space	243	-
Total	611	314



KEY

▤ Developed Land

▒ Subdividable / Developable Land

☐ Restricted Open Space

FIGURE 2.11 Developable Analysis of a Watershed

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Phosphorus Loading Analysis

A nutrient loading analysis estimates the quantities of the nutrient of concern discharged by each potential contributor and then the overall final concentration in the receiving ground or surface waters. The loading analysis is a very effective means of quickly assessing the water quality impacts because it integrates the contributions from every source within a watershed.

Table 2.3 summarizes the loading rates for various sources of phosphorus and nitrogen within the watershed. These loading rates can then be applied to the results of the watershed land use analysis to determine total watershed loading rates to the lake. The total watershed loading rate can then be divided by the total hydrologic inputs to determine predicted total nutrient concentrations in the lake.

TABLE 2.3 Representative values for nutrient export rates and input rates for various land uses. All values are median and are only approximations owing to the highly variable nature of data on these rates.

Land Use	Total Phosphorus	Total Nitrogen
A. EXPORT rates (lbs/acre/yr)[1]		
Forest	0.2	2.2
Nonrow crops	0.6	5.4
Pasture	0.7	13.0
Mixed agriculture	1.0	4.5
Row crops	2.0	8.0
Feedlot, manure storage	227.0	2600.0
Urban	1.8	-----
B. Total atmospheric input rates (lbs/acre/yr)[2]		
Forest	0.23	5.8
Agricultural/rural	0.25	12.0
Urban industrial	1.01	19.0
C. Wastewater input rates (lbs/capita/yr)[3]		
Septic tank input[4]	3.2	5.5

[1] Source: Reckhow et al. 1980, Figure 3.

[2] Source: Reckhow et al. 1980, Table 13.

[3] Source: Reckhow et al. 1980, Table 14 (Phosphorus) and Nelson et al. 1988 (Nitrogen).

[4] This loading rate assumes no attenuation of phosphorus in soils. The most significant loadings from septic systems will be those within 100 meters of the lake or tributaries.

This analysis can be performed for historical, existing and future (build-out/saturation) development scenarios. Historical septic system densities may be evaluated for model calibration purposes to account for the likely lag time between the construction of a new septic system and the introduction of nutrients from that system into a downgradient lake. In fast soils (sand and gravel outwash deposits), the ground water flow velocity may be approximately 1 foot/day. Viruses and bacteria in effluent from a septic system located 2,000 feet from the lake's shoreline would take 2,000 days or 5.5 years to reach the lake. Phosphorus is easily attenuated in soils, such that studies documented by EPA have shown that the primary source of phosphorus is within 100 meters of a lake. However, over time in areas with

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SECTION 3.

AQUATIC PROBLEMS AND THEIR IDENTIFICATION

LECTURE OUTLINE

SECTION 3: AQUATIC PROBLEMS AND THEIR IDENTIFICATION

1. COMMON AQUATIC PROBLEMS

a. Weed Infestation

1. Causes
   - overfertilization
   - suitable sediment
   - sufficient light
   - absence of toxic materials
   - insufficient grazing
   - appropriate water level
   - lack of physical disturbance

2. Ecological implications
   - exotic invasion
   - habitat alteration
   - fluctuating oxygen
   - algal inhibition
   - food resource

3. Use impairment
   - potable supply
   - contact recreation
   - fishing
   - boating
   - aesthetics

b. Algal Bloom

1. Causes
   - overfertilization
   - sufficient light
   - lack of toxic substances
   - insufficient grazing

2. Ecological implications
    - food resource
    - fluctuating oxygen
    - taste and odor
    - toxicity to animals/humans
    - inhibition of rooted plants

3. Use impairment
    - potable supply
    - contact recreation
    - fishing
    - aesthetics

c. Fish Stunting

1. Causes
    - insufficient predation
    - excessive refuges
    - food shortages
    - fishing practices

2. Ecological implications
    - increased food for predators
    - decreased zooplankton
    - increased algae

3. Use impairment
    - fishing
    - aesthetics
    - contact recreation

d. Fish Kill

1. Causes
    - natural mortality
    - fishing pressure
    - temperature change
    - insufficient oxygen
    - toxic substances

2. Ecological implications
   - loss of trophic level
   - nutrient recycling
   - food resource loss

3. Use impairment
   - fishing
   - potable supply

e. Swimmers Itch

1. Causes
   - suitable habitat with hosts for schistosomes

2. Ecological implications
   - parasitism

3. Use impairment
   - contact recreation

f. Leeches

1. Causes
   - suitable habitat with hosts for leeches

2. Ecological implications
   - parasitism

3. Use impairment
   - contact recreation

g. Aggressive Waterfowl

1. Causes
   - desirable habitat
   - overabundant birds

2. Ecological implications
   - fertilization
   - predation/grazing
   - fecal bacteria loading

3. Use impairment
    - contact recreation
    - potable supply

h. Shallowness

1. Causes
    - natural morphometry
    - erosion/sedimentation
    - accumulated organic matter

2. Ecological implications
    - plant growth
    - habitat change
    - sediment resuspension

3. Use impairment
    - contact recreation
    - boating
    - fishing
    - flood control
    - water supply

i. Inhospitable Lake Bottom

1. Causes
    - type of sediment
    - obstructions

2. Ecological implications
    - habitat structure
    - oxygen demand
    - taste and odor

3. Use impairment
    - contact recreation
    - boating
    - potable supply

j. Taste and Odor

1. Causes
    - algal blooms

- weed infestations
- low oxygen chemistry
- fish kill
- watershed inputs

2. Ecological implications
    - sensory impacts on fauna

3. Use impairment
    - potable supply
    - contact recreation
    - aesthetics
    - boating
    - fishing
    - hunting

k. Color and Turbidity

1. Causes
    - watershed inputs
    - sediment-water interaction
    - algae

2. Ecological implications
    - predation
    - plant growth
    - fertilization

3. Use impairment
    - potable supply
    - contact recreation
    - aesthetics
    - fishing

l. User Conflicts

1. Causes
    - incompatible uses
    - insufficient space
    - inadequate user management

2. Ecological implications
    - direct interference
    - habitat destruction

3. Use Impairment
    - Any or all, depending on conflict

2. CAUSES OF LAKE CHANGE

a. Watershed Alteration

1. Natural changes
    - sediment build-up
    - fertilization
    - species replacement
    - catastrophic events

2. Urbanization impacts
    - runoff
    - erosion
    - waste disposal

3. Agricultural impacts
    - runoff
    - erosion
    - waste disposal

b. Exotic Species Invasion

1. Nuisance plants
2. Nuisance animals

c. Lake Use/Management

1. User impacts
2. Management impacts

3. DIAGNOSTIC STUDY METHODOLOGY

a. Useful Information

1. Lake Management Objectives
    - Existing and desired uses of the lake
    - Priority of uses
    - Special features which must be considered

2. Physical Lake Features
    - Map of lake shape, lake area
    - Map of water depth, mean and maximum depths, volume
    - Map of soft sediment depth

3. Physical Watershed Features
    - Detailed topographic maps
    - Watershed delineation
    - Sub-watershed delineations
    - Map of land uses
    - Delineation of sewered and non-sewered areas
    - Delineation of storm drainage pipelines
    - Geology and soils maps

4. Historical Information on Lake and Watershed Uses
    - Old accounts
    - Old maps

5. Limnological Data
    - Flow (surface and ground waters)
    - Water quality (nutrients, pH, oxygen, bacteria, etc.)
    - Sediment quality (organic content, nutrients, metals)
    - Biological quality (algae, vascular plants, invertebrates, fish)

b. Key Indicators: Watershed

1. Watershed: lake area ratio
2. Erodibility of soils
3. Land use
4. Road density
5. Lake access

c. **Key Indicators: Lake**

1. Lake area
2. Shallowness ratio
3. Hydraulic residence time
4. Shoreline development
5. Water clarity
6. Littoral zone plant coverage
7. Bottom sediment type
8. Presence of specific biota

d. **Water Quality Monitoring**

1. Design considerations
    - parameters to be assessed
    - stations to be sampled
    - frequency of sampling
    - cost
    - laboratory turnaround time
    - statistical needs
    - sampling protocol

2. Typical parameters
    - water flow (velocity X area)
    - total phosphorus
    - soluble reactive phosphorus
    - total soluble phosphorus
    - ammonium nitrogen
    - nitrate nitrogen
    - total Kjeldahl nitrogen
    - dissolved oxygen
    - temperature
    - alkalinity
    - pH
    - conductivity
    - total dissolved solids
    - chlorides
    - total suspended solids
    - turbidity
    - Secchi disk transparency
    - chlorophyll a
    - iron
    - fecal bacteria

3. Sampling stations
    - vertical levels in distinct lake basins
    - inlet streams/pipes
    - outlet(s)
    - key upstream points

4. Sampling frequency
    - daily
    - weekly
    - monthly
    - seasonally
    - annually

5. Costs
    - sample collection
    - sample analysis
    - data analysis

6. Laboratory turnaround time
    - holding time
    - analysis time
    - data processing time

7. Statistical needs
    - precision
    - accuracy
    - significant differences

8. Sampling protocol
    - sample containers
    - sample volumes
    - preservation
    - labelling
    - representative sampling
    - compositing
    - flow measures
    - field notes

e. Pollutant Loadings and Budgets

1. Purpose

2. Evaluating loads
    - export models
    - in-lake models
    - empirical data

3. Constructing budgets

4. DETERMINING APPROPRIATE LAKE USES

a. Range of Uses

1. Contact recreation
2. Passive uses/aesthetics
3. Non-power boating
4. Power boating/skiing
5. Fishing
6. Hunting
7. Consumptive supply
8. Power supply
9. Cooling supply
10. Flood control
11. Ice sports

b. Influence of Watershed Features on Lake Uses
c. Influence of Lake Features on Lake Uses
d. Influence of Lake Use on Lake Features
e. Influence of Lake Uses on Other Lake Uses
f. Establishing Priorities

1. Lake/watershed analysis
2. User surveys
3. Building concensus

5. POST-TREATMENT MONITORING

6. MINI-TEST: MONITORING PROGRAM DESIGN

Aquatic Problems And Their Identification

COMMON AQUATIC PROBLEMS

Weed Infestation

Common aquatic problems include weed infestation, algal blooms, fish stunting, fish kill, swimmer's itch, leeches, aggressive waterfowl, shallowness, inhospitable lake bottom, taste and odor, color and turbidity, and user conflicts. Not all are likely to occur in a single system, and not all lake uses are impacted by each problem, but any of these problems can greatly diminish the utility of a lake in one way or another. Some problems are entirely natural, but most can be exacerbated by human influence.

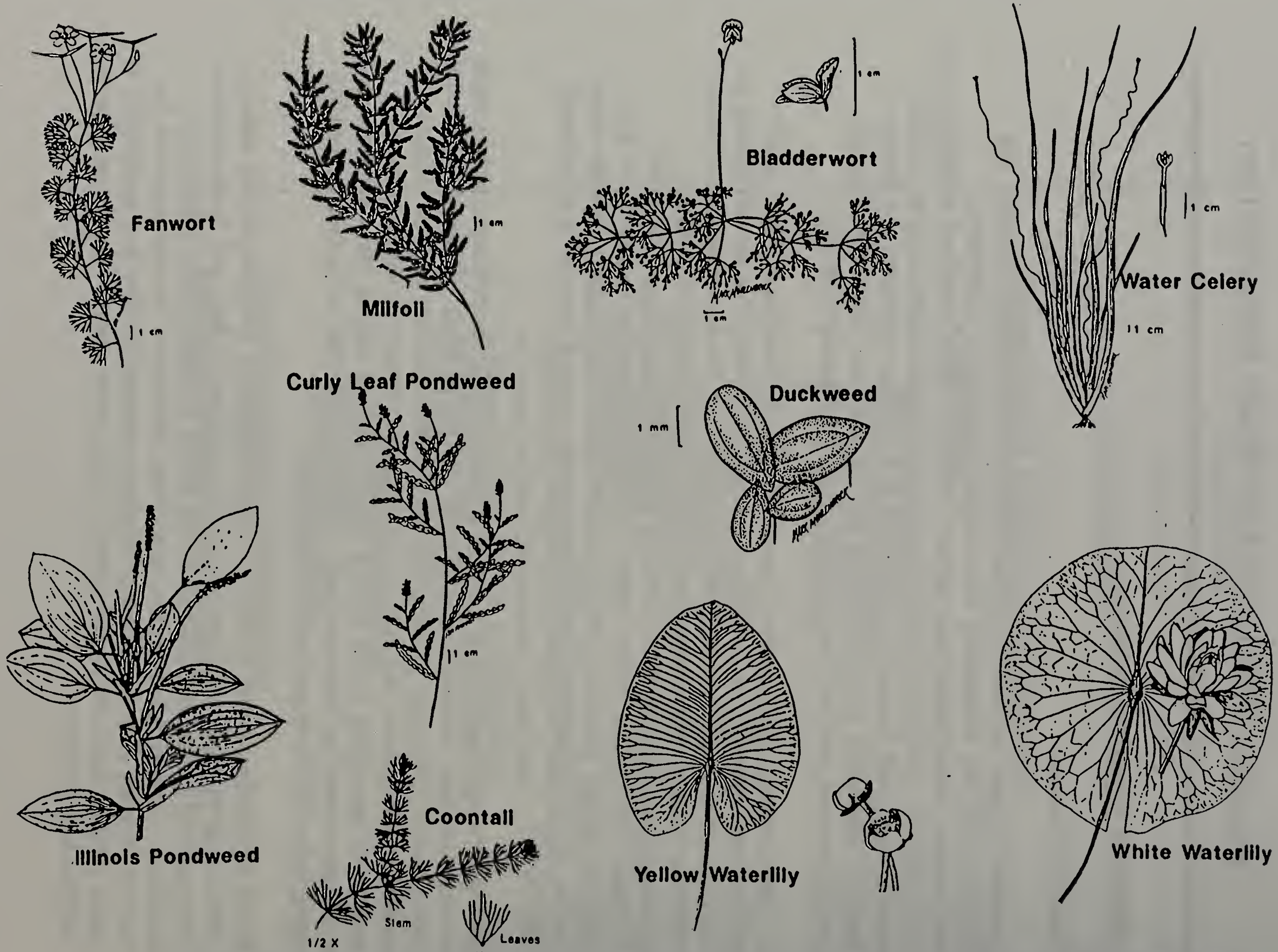
A weed is simply an unwanted plant. Excessive abundance of any plant species may therefore be considered a weed infestation, but certain species are more prone to become nuisances than others. In Massachusetts, the primary nuisance species include Myriophyllum (several species of milfoil), Ceratophyllum demersum (coontail), Cabomba caroliniana (fanwort), Valisneria americana (water celery), Nymphaea odorata (white water lily), Nuphar advena (yellow water lily or spatterdock), Utricularia (bladderwort), Lemna minor (duckweed), and Potamogeton (several species of pondweed) (Figure 3.1).

Infestations are the result of suitable habitat, which encompasses factors such as sediment type, nutrient supply, light, and water level. Absence of physical disturbance, substantial grazing and toxic substances aids growth. Nearly all rooted aquatic plants derive the vast majority of their nutrition from the sediment; improving water quality will do little to reduce plant growths once a nuisance level has been reached. Control techniques are aimed at making some aspect of the plant habitat unsuitable.

Weed infestations provide food for some waterfowl and insects, but make it difficult for fish to forage, people to swim, anglers to fish, and boats to move. Taste and odor may be imparted to the water, but algal blooms are often inhibited. Oxygen levels in the water may fluctuate to the detriment of the fish community as a consequence of photosynthesis by day and respiration at night. Some plants are rather attractive, but many people find dense growths unappealing to view.

FIGURE 3.1

COMMON AQUATIC PLANTS KNOWN TO CAUSE NUISANCE CONDITIONS



SOURCES: Illinois Dept. of Conservation 1988, Rawinski et al. 1979, Westerdahl and Getsinger 1988

Algal Blooms

Algal blooms are the unrooted equivalent of weed infestations, and involve high concentrations of microscopic algae in the water column (Figure 3.2). Some species of bluegreen algae (actually photosynthetic bacteria) have gas vacuoles which allow them to float, forming visible surface scums. Some species of algae have flagella which allow them to position themselves in the water column, creating bands of color at different depths. Mats of filamentous algae, particularly green and bluegreen forms, often trap gases generated by photosynthesis and respiration and float to the surface.

Unlike rooted aquatic plants, algae gain their nutrition through the water column. They also require suitable light and flourish in the absence of toxic substances and grazing zooplankton. Reducing nutrient loads to a lake will reduce algal biomass if nutrient availability controls productivity. Otherwise, managers must resort to reducing light, increasing grazing by zooplankton or fish, or applying chemicals toxic to the algae.

Algae are an important link in the food chain, but dense accumulations signal an ecological imbalance which may have negative consequences for the entire system. Oxygen levels may fluctuate to extremes due to algal metabolism, substances released by algae may negatively affect other organisms in the water (including humans) or impart taste and odor, and rooted plants may be shaded to the point of elimination. Consumptive uses of water, contact recreation and aesthetics are negatively affected, and fishing satisfaction may decline even though overall fish production is likely to increase.

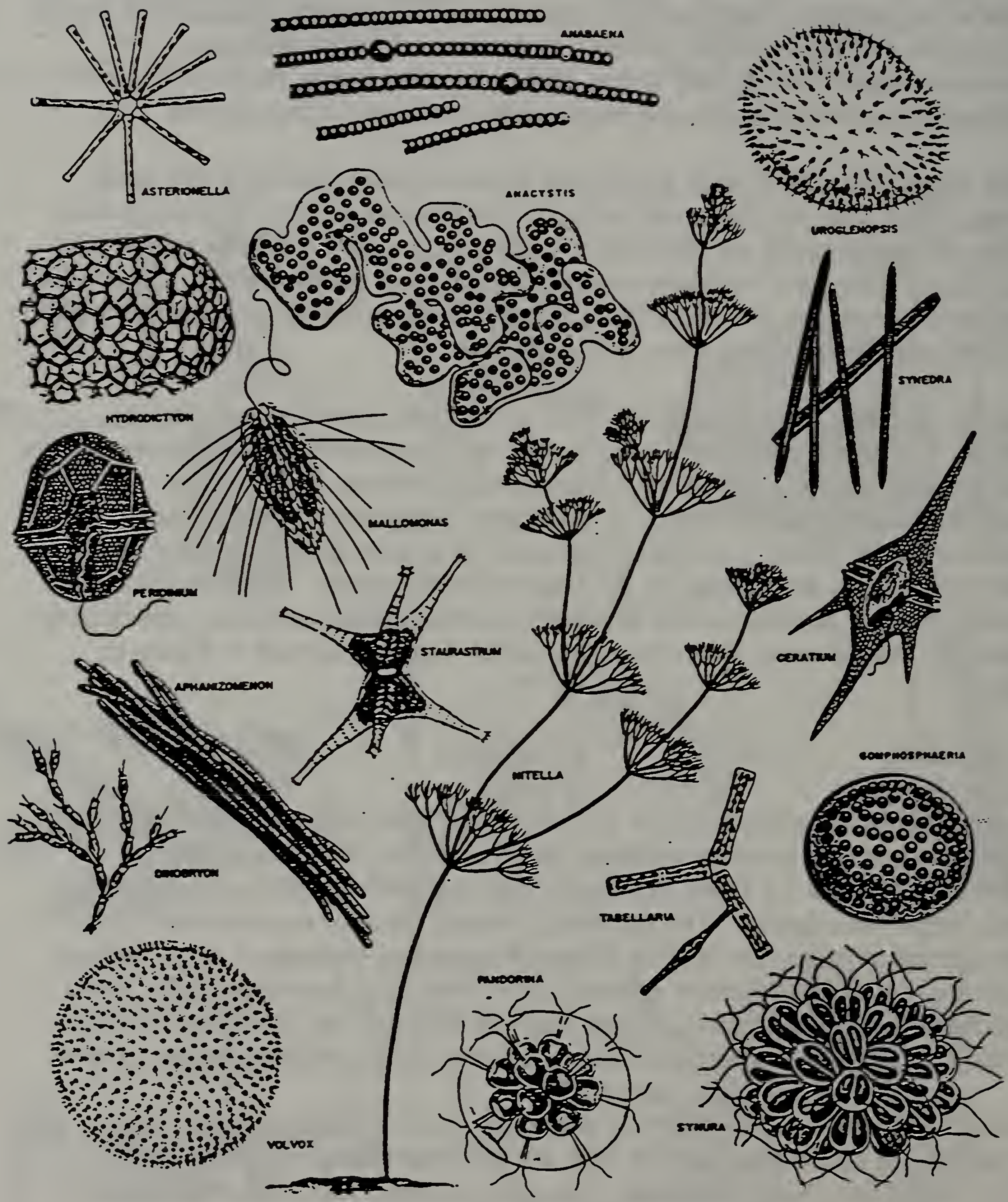
Fish Stunting

Fish stunting is a consequence of too many fish and too little food. If predators are scarce from overfishing or other losses, the forage species normally consumed by those predators may expand dramatically through several large year classes. The generally annual cycle of reproduction and hardy nature of most fish species allows population expansion to go beyond the optimal level for desirable growth rates. Stunting is promoted by weed infestations and algal blooms, which make it difficult for predatory fish to find the forage species and limit feeding success by the forage species as well.

Stunted fish populations generally make for poor fishing, although many fish may be caught and the large food base for predators may result in a few trophy- sized fish being available. The glut of small fish tends to minimize zooplankton size and biomass, eliminating grazing control of algae and

FIGURE 3.2

TASTE AND ODOR ALGAE



SOURCE: Palmer 1959

promoting algal blooms. Fishing, contact recreation and aesthetics may all therefore be negatively affected. Restructuring of the fish community can be accomplished by artificially reducing the density of stunted fish through chemical or physical (e.g., netting, drawdown) means or by increasing the density of predators by stocking.

Fish Kills

Fish kills may result from the addition of toxic substances, severe fluctuations in oxygen or temperature, diseases, or starvation. Increased mortality during late winter and spring is common, as many fish are preparing for reproduction, food resources are often at their lowest, and oxygen and temperature levels fluctuate substantially (especially in shallow waters where spawning most often occurs). Noticeable kills of alewife, yellow perch and sunfish are not unusual at this time, and managers must resist the temptation to assume that there has been a toxic spill or similar incident. The best evidence of unnatural mortality comes from substantial, simultaneous kills of multiple species over a wide size range; natural mortality tends to focus on individual species or size classes.

Major fish kills may result in the loss of one or more trophic levels, with a cascading effect on other components of the system. Fishing will obviously be negatively affected, but other lake uses may be impaired as well, depending on the indirect effects of the loss of fish from the system.

Swimmer's Itch

Swimmer's itch is caused by a parasite known as a schistosome, which lives part of its life in certain snails. Lakes with substantial leafy plant populations and moderate to high pH are most suitable for the snails, and are therefore more prone to harbor schistosomes. Contact recreation is most negatively affected by the presence of schistosomes.

Leeches

Leeches belong to another parasitic group which utilizes a variety of hosts and may attach to humans in the water. As humans spend relatively little time in the water and leeches are aquatic, humans are not the preferred host of most leeches. Nevertheless, leeches do sometimes attach to humans, and can make contact recreation most unpleasant. Leeches tend to be most common in slightly acidic waters with substantial refuges for the relatively unprotected leeches; weed infested areas, organic sediments and gravelly substrates are likely hideouts.

Aggressive Waterfowl

If waterfowl densities are high or a recreation area overlaps with strongly preferred habitat, birds may act aggressively toward humans. Swans and geese are the primary combatants, but many other species of waterfowl may become aggressive during breeding season. Aside from direct negative interaction with swimmers or shoreline users, waterfowl add nutrients and fecal bacteria to the system. If birds are abundant, overfertilization or health hazards may result. Extensive feeding may alter aquatic plant community structure, which in turn may affect other components of the lake.

Shallowness

Shallowness may be a function of natural lake morphometry or progressive sediment accumulation, either from erosion in the watershed or in-lake production by plants. Depth is an important feature of a lake with regard to ecology and recreation. Shallow areas promote rooted plant growth and sediment resuspension, and represent an entirely different habitat from deeper areas. As most contact recreation takes place in shallow areas, the need for careful management of shallow water areas is suggested. Extreme shallowness may negatively affect contact recreation, boating, fishing, flood control and water supply uses.

Inhospitable Sediments

The nature of the sediment and presence of any obstructions in shallow water can make the lake bottom inhospitable for many uses in shallow areas. Bathers prefer sand to cobble or organic muck, and boulders and stumps represent hazards to both swimmers and boaters. Organic substrates tend to create a substantial oxygen demand, and may impart taste and odor to the overlying water. A variety of sediment types contributes to habitat diversity, however, and stumps and boulders make excellent fish habitat.

Taste and Odor

Taste and odor can be caused by substances produced within the lake, most often by weeds or algae, or by compounds carried into the lake with watershed runoff, especially where urban or agricultural storm drainage is involved. Fish kills or sediment-water interaction during periods of low oxygen concentration can also cause detectable taste and odor in a lake. The rate of flushing of the lake will greatly affect the severity of tastes and odors and their duration. Taste and odor in the water detract from potable supply use and contact recreation, and can negatively impact aesthetics, boating, fishing and hunting. Fish or invertebrates which depend on olfactory sense for navigation or feeding may be adversely impacted as well.

Color and Turbidity

Color and turbidity are distinct qualities of a lake. The former is a function of dissolved substances while the latter is dependent upon suspended matter. Color is most often a consequence of watershed inputs, especially from wetlands, although prolonged interaction between water and sediment in lakes with low flushing rates can cause detectable color. In Massachusetts the most common colors are shades of brown, derived from tannic and humic acids associated with vegetative decay in acid waters. Turbidity may be caused by watershed inputs of suspended solids or by internal production of particles, usually as algae or resuspended detritus. Particles may be resuspended by wind action, currents, boats or swimmers.

Color and turbidity may affect the productivity of the lake, generally having a limiting effect on biological activity. However, most recreational and consumptive supply uses of lakes are negatively affected by color and turbidity. Lakes in which visibility is restricted to less than four feet by color or turbidity are not legally useable for contact recreation in Massachusetts. The visibility requirements are found in the State Sanitary Code. Fishing tends to be poor in such lakes as well, boating can be hazardous, and aesthetic appeal is diminished.

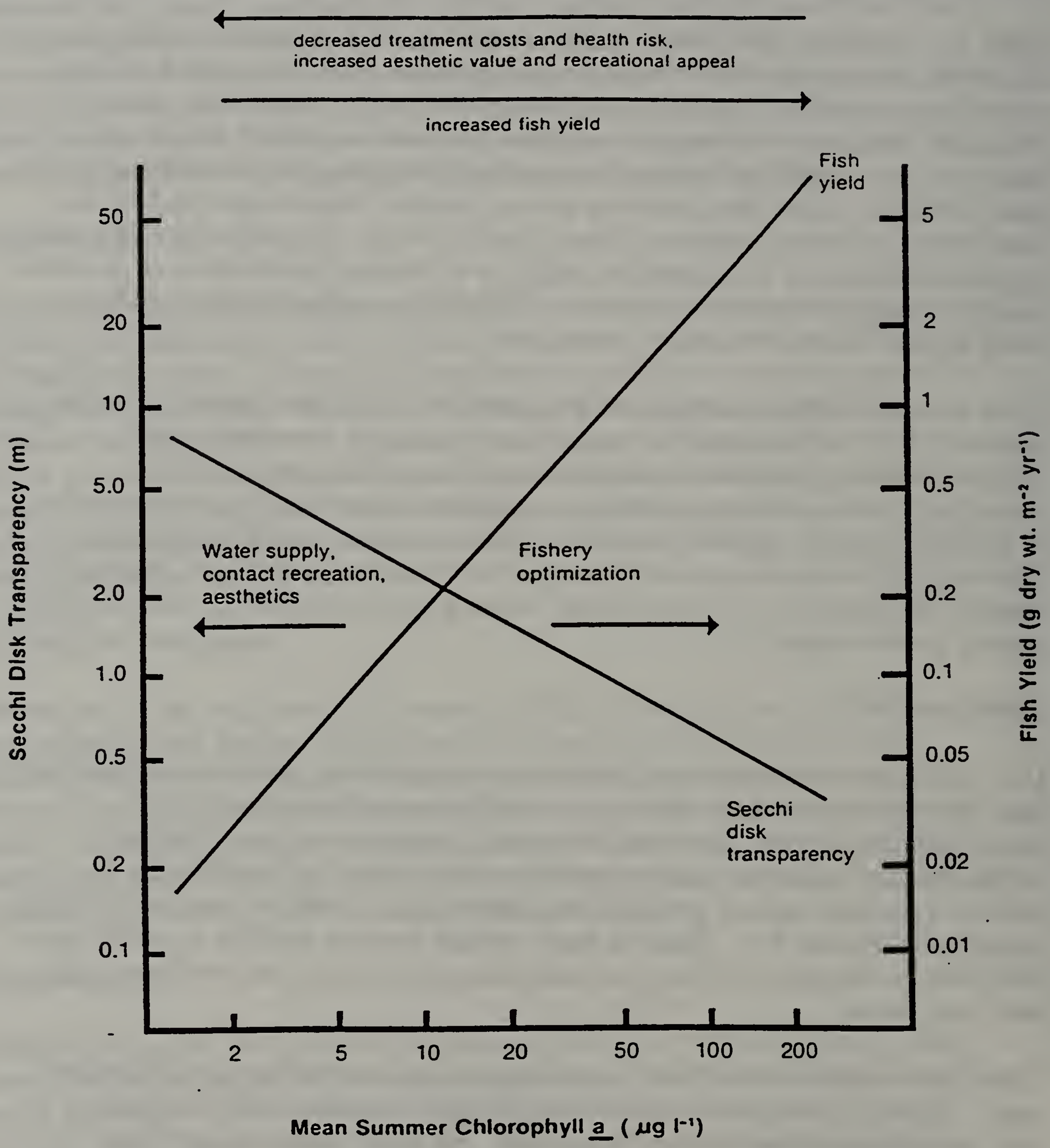
User Conflicts

User conflicts constitute some of the most troublesome problems with which lake managers must deal. Some user conflicts result from basic incompatibility of uses, as with fishing and contact recreation. Contact recreation demands the clearest possible water, while fish availability is related to overall system productivity, which tends to be proportional to algal abundance (Figure 3.3). There is some middle level of fertility at which most users can be satisfied, but the best swimming lake is not the best fishing lake and vice versa.

Other user conflicts stem from insufficient space availability for all desired uses. Zoning a lake for different uses is highly desirable when competing uses interfere with each other (Figure 3.4), but many lakes are not large enough to allow spatial restrictions without reducing user satisfaction or employing access limits. Temporal restrictions, such as an every other day rule for motorized watercraft, can be substituted for spatial restrictions on

FIGURE 3.3

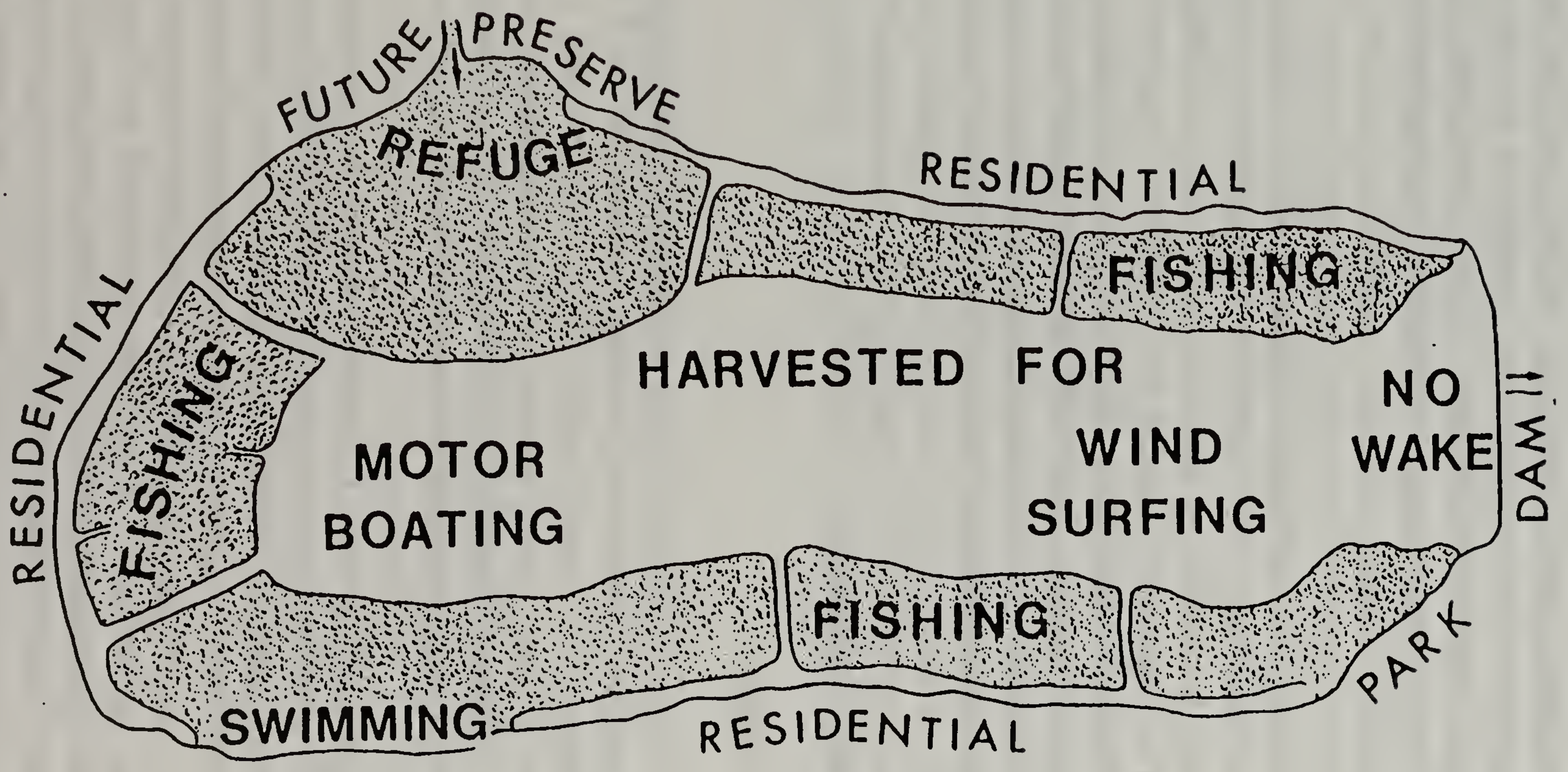
RELATION BETWEEN COMMON LAKE MANAGEMENT OBJECTIVES AND CHLOROPHYLL A



SOURCE: Wagner and Oglesby 1984

FIGURE 3.4

AREAL LAKE ZONING TO MINIMIZE USER CONFLICTS



SOURCE: Engel 1989

some lakes, but complete satisfaction will not be achieved by this method either.

Still other user conflicts are the result of inadequate user management. Appropriate rules must be enforced, and managers should periodically survey lake users to assess needs and desires. Adjustments in management practices, such as hours of operation, access availability, and facilities offered, are likely to be necessary.

User conflict evaluation must also consider the lake itself. After all, the inhabitants of the lake (e.g., fish, waterfowl, plants) are lake users too. If the ecology of the lake is ruined by overuse, many uses, including those responsible for the degradation, may be impaired. Excessive boating in a shallow lake will often result in turbidity levels too high for safe or appealing contact recreation or boating, and will diminish aesthetic value. Plant abundance may decline to levels insufficient to sustain waterfowl or certain fish populations. Overfishing a lake can have similarly extensive impacts.

CAUSES OF LAKE CHANGE

Watershed Alteration

It is important to note that most lakes experience some degree of change naturally. Succession of plant and animal species within a lake ecosystem will result in change to a lake's trophic state. The process of eutrophication can occur naturally over a long period of time (hundreds to thousands of years). Human-induced impacts, resulting in "cultural" eutrophication, can accelerate this process to a period of years or decades.

Most lake changes are the result of changes within the watershed. Some of these changes are natural, as with gradual succession of vegetation types or catastrophic events such as hurricanes, both of which affect nutrient and sediment inputs to lakes. Other changes are brought about by human activities, which can be conveniently divided into two broad categories: urbanization and agriculture. Activities associated with each result in changes in runoff generation, erosion and waste disposal. The magnitude of the impact on the receiving lake and the rate of change in lake features depends upon a variety of watershed features discussed elsewhere in this course.

Exotic Species Invasion

Some lake changes are the result of an invasion of a new species, one that was not previously found in the lake. These "exotic" species (as opposed to indigenous species) may take hold rapidly and either colonize unused habitat or outcompete existing plants or animals. Extremely successful invaders often become nuisances by virtue of density, and can drastically change the biological structure of the lake ecosystem. Eurasian milfoil (Myriophyllum spicatum) is a prime example of an exotic species which can markedly change the ecology and recreational utility of a lake in a period of less than five years.

Lake Use/Management

Still other lake changes are brought about by user impacts or management efforts. The impact of water supply or flood control uses of a lake can be extreme, depending upon the magnitude of water level fluctuations and morphometry of the lake. Recreational uses tend to have less widespread effects, although power boating has been known to alter shallow lake ecology as described above. Management efforts which involve large scale restoration projects are likely to markedly alter lake features, hopefully for the better, but often with side effects.

DIAGNOSTIC STUDY METHODOLOGY

Useful Information

A diagnostic study is simply the collection of information useful to the assessment of lake condition and influences on that condition, with an analysis of what makes the lake what it is. A great variety of informational items may be valuable in such a study (Table 3.1), but the final assessment will probably boil down to the influence of a few key variables. The key is to figure out which variables are most critical to the functioning of the lake and how they might be controlled to protect or improve lake condition with respect to a set of management goals.

Since the assessment depends to a large extent on objectives for lake management, the study should start with a clear statement of management goals. The priority of uses should be established, the current uses should be elucidated, and any special features or considerations should be noted. The first real assessment work involves determining the physical qualities of the lake and its watershed. For the lake, shape, area, depth, volume, and sediment quantity are of prime importance. For the watershed, general

TABLE 3.1

INFORMATION USEFUL TO THE MANAGEMENT OF LAKES AND PONDS

The following list includes pieces of information which are useful and in many cases necessary to the effective management of an aquatic system. The level of detail required varies among systems, and some items might even be inapplicable to certain systems.

A. Lake Management Objectives
   1. Existing and desired uses of the lake
   2. Priority of uses
   3. Special features which must be considered

B. Physical Lake Features
   1. Map of lake shape, lake area
   2. Map of water depth, mean and maximum depths, volume
   3. Map of soft sediment depth

C. Physical Watershed Features
   1. Detailed topographic maps of area
   2. Watershed delineation
   3. Sub-watershed delineations
   4. Map of land uses
   5. Delineation of sewered and non-sewered areas
   6. Delineation of storm drainage pipelines
   7. Geology and soils maps

D. Historical Information on Lake and Watershed Uses
   1. Old accounts
   2. Old maps

E. Limnological Data
   1. Flow (surface and ground waters)
   2. Water quality (nutrients, pH, oxygen, bacteria, etc.)
   3. Sediment quality (organic content, nutrients, metals)
   4. Biological quality (algae, large plants, invertebrates, fish)

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

topography, area, drainage pattern, land use, and soils are paramount. All this information should be placed in a historical context through examination of old maps and records to allow assessment of past changes.

The study then proceeds with a collection of limnological data including information on the chemical and biological aspects of the lake. Past data are valuable, and may be suitable for analysis of current conditions, but it is strongly recommended that new data be collected for at least those parameters which seem of critical concern from an evaluation of existing data. As it is very helpful to construct budgets for various substances, concentrations of these substances and flow values must be obtained. Parameters of potential utility are listed in Table 3.2.

Key Indicators

Even before all the necessary water quality data has been collected and the budgets analyzed to determine key inputs and sources, it is useful to evaluate the system based on a number of simple indicator parameters which relate to management needs (Tables 3.3 and 3.4). Indicators for the watershed include the watershed:lake area ratio, the erodibility of watershed soils, dominant land use, density of roads, and degree and types of lake access. Lake indicators of particular utility include area, degree of shallowness, hydraulic residence time (the inverse of flushing rate), shape of the shoreline, water clarity, coverage by rooted aquatic plants, nature of the lake bottom, and presence of specific biota.

Once a lake and its watershed have been classified according to these indicator parameters, the management needs and use potential should become clear. Water quality data verifies the indications, facilitates further assessment, and often allows determination of where the greatest gain can be made for the least expenditure.

Water Quality Monitoring

Many of the physical and biological parameters are assessed as a one-time effort. Once features such as pond morphometry, soft sediment depth, rooted plant distribution, and fish community structure have been determined there is no need to repeat the measures on a frequent basis. Zooplankton might be assessed seasonally and phytoplankton checked on a monthly basis, and fecal bacteria might be assessed on a biweekly schedule. Water quality measurements, which usually incorporate phytoplankton and bacterial analyses, tend to be performed on at least a monthly schedule, however. This requires more planning and logistical effort, as well as increased funding.

TABLE 3.2

COMMONLY ASSESSED MONITORING PARAMETERS WITH NOTES ON ASSOCIATED COST AND UTILITY

PARAMETER	UNIT OF ANALYSIS	RANGE OF COST FOR ANALYSIS ($)	NOTES ON PARAMETER UTILITY
Flow	station	5-50	Essential for pollutant budgets and hydrology
Total phosphorus	sample	10-40	Critical plant nutrient, all forms
Soluble reactive phosphorus	sample	8-20	Critical plant nutrient, readily available form
Total soluble phosphorus	sample	10-40	Critical plant nutrient, assumed bioavailable form
Ammonium nitrogen	sample	10-25	Critical plant nutrient, possible health risk
Nitrate/nitrite nitrogen	sample	8-20	Critical plant nutrient, possible health risk
Total Kjeldahl nitrogen	sample	20-50	Ammonium plus organic nitrogen forms
Dissolved oxygen	station	5-25	Essential for most desirable forms of aquatic life
Temperature	station	2-5	Affects many reactions, solubilities, process rates
Alkalinity	sample	5-15	Indicates buffering capacity for acid inputs
pH	sample	5-15	Indicates level of acid concentration
Conductivity	sample	5-15	Indicates dissolved substances and overall fertility
Total dissolved solids	sample	10-25	Fertility indicator, substances dissolved in lake
Chlorides	sample	5-15	Salt indicator, often major dissolved substance
Sodium	sample	5-15	Potential health risk, common dissolved substance
Total suspended solids	sample	12-25	Represents all particle forms in water
Turbidity	sample	5-15	Clarity indicator, related to suspended solids
Secchi disk transparency	station	2-5	Clarity indicator, related to suspended solids
Iron	sample	8-20	Important and common metal, taste factor, P binder
Other trace metals	sample	12-25	Variety of possibly toxic metals, health risks
Chlorine	sample	8-15	Result of chlorination, treatment facility marker
Sulfate	sample	8-15	Substrate for anaerobic metabolism, acid indicator
Color	sample	8-15	Related to dissolved substances and visual properties
Odor	sample	8-15	Related to dissolved substances and sensory features
Biochemical oxygen demand	sample	25-50	Level of oxygen removal through decomposition
MBAS surfactants	sample	25-50	Detergent indicator, aid in sorting P sources
Oil and grease	sample	25-80	Suggests organic matter level, possible toxicity
Total organic carbon	sample	30-60	Suggests organic matter level, possible toxicity
Volatile organic compounds	sample	110-200	Scan of variety of possibly toxic materials
Pesticide scan	sample	75-150	Scan of variety of possibly toxic materials
PCB's	sample	60-125	Possible health risk, human impact indicator
Fecal coliform	sample	8-30	Possible health risk, sewage contamination indicator
Fecal streptococci	sample	8-30	Modifies assessment via fecal coliform
Chlorophyll a	sample	25-60	Represents algal biomass, clarity indicator
Phytoplankton abundance	sample	30-100	Eval. of community structure, ecological indications
Zooplankton abundance	sample	30-100	Indicates grazing potential, food for small fish
Macrophyte abundance	lake	1000-5000	Suggests nuisance potential, ecological indications
Macroinvertebrate abundance	sample	30-100	Suggests sediment quality, fish food resource
Fish community structure	lake	1000-5000	Eval. of community structure, ecological indications

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.3

WATERSHED FEATURES WHICH INFLUENCE RECREATIONAL UTILITY AND IMPACTS

1. **Watershed:lake area ratio**
    a. Low (<10:1)
    b. Medium (10-25:1)
    c. High (25-50:1)
    d. Very high (>50:1)

2. **Erodibility of soils**
    a. Low (high permeability, flat slopes, high cover)
    b. Medium (one of above opposite, others same)
    c. High (two of above opposite, other same)
    d. Very high (low permeability, steep slopes, low cover)

3. **Land use**
    a. Dominated by forest or wetland
    b. Dominated by agriculture (excluding sugarbush)
    c. Dominated by urbanized uses

4. **Road density**
    a. Low
    b. Medium
    c. High
    d. Very high

5. **Lake access**
    a. No formal access
    b. Primitive trails or beaches
    c. Developed boat ramps or beaches

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.4

LAKE FEATURES WHICH INFLUENCE RECREATIONAL UTILITY AND IMPACTS

1. **Lake area**
   a. Low (<20 ac)
   b. Medium (20-100 ac)
   c. Large (100-300 ac)
   d. Very large (>300 ac)

2. **Shallowness ratio**
   (area <5 ft deep/total area)
   a. Low (<0.10)
   b. Medium (0.10-0.25)
   c. High (0.25-0.50)
   d. Very high (>0.50)

3. **Hydraulic residence time**
   a. (<21 days)
   b. (21-90 days)
   c. (90-365 days)
   d. (>365 days)

4. **Shoreline development**
   (shoreline length/circumference of circle with lake area)
   a. Low (<1.5)
   b. Medium (1.5-3.0)
   c. High (>3.0)

5. **Water clarity**
   a. Low (<4 ft)
   b. Medium (4-8 ft)
   c. High (8-15 ft)
   d. Very high (>15 ft)

6. **Littoral zone coverage by plants**
   a. Low (<25%)
   b. Medium (25-50%)
   c. High (50-75%)
   d. Very high (75-100%)

7. **Bottom sediment type**
   a. Cobble
   b. Gravel or sand
   c. Silt or clay
   d. Organic muck
   e. Boulders or stumps

8. **Presence of specific biota**
   a. Parasites or other nuisance species
   b. Rare or endangered populations
   c. Fish desired by anglers
   d. Waterfowl desired by hunters

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

To actually collect the needed water quality data, a carefully considered plan of action is strongly recommended. Not all information is equally relevant, and most organizations have limited budgets. Critical design elements include the parameters to be assessed, the stations to be sampled, the frequency of sampling, the cost of the collection, lab analyses, and data interpretation, the laboratory turnaround time, the statistical needs of the study, and the sampling protocols to be applied.

Selecting parameters is simplified by having clear management goals and a historical data base. For most lake studies, flow, forms of nitrogen and phosphorus, temperature, oxygen, water clarity (usually by Secchi disk) and fecal bacteria (e.g., coliform or streptococcus) are the most assessed parameters. Alkalinity, pH, conductivity, chlorides, iron, suspended or dissolved solids, turbidity and chlorophyll have merit, but can be assessed less frequently with little consequence. The goals should be considered carefully, however; more measurements of a critical parameter must be weighed against fewer measurements of that parameter and some of other less clearly critical parameters.

Sampling station selection is largely common sense tempered with knowledge of the system and periodic adjustments as dictated by the collected data. Figure 3.5 depicts the sampling stations associated with a study of Richmond Pond. Stations 1, 2, 3 and 3A are inlets, station 4 is at the deepest part (>50 ft) of the pond's one distinct basin (with sub-stations at the surface, mid-depth, and bottom), and station 5 is the outlet. Stations 6 through 12 are stormwater drainage pipes or ditches. S1 through S3 are sediment sampling locations, selected as representative of separate sediment types within the pond. Auxiliary stations were set up on the tributaries upstream of the inlets for two-time assessment of water quality. Stations were located at major branching points for the major tributaries, to facilitate isolation of any problem sub-watersheds.

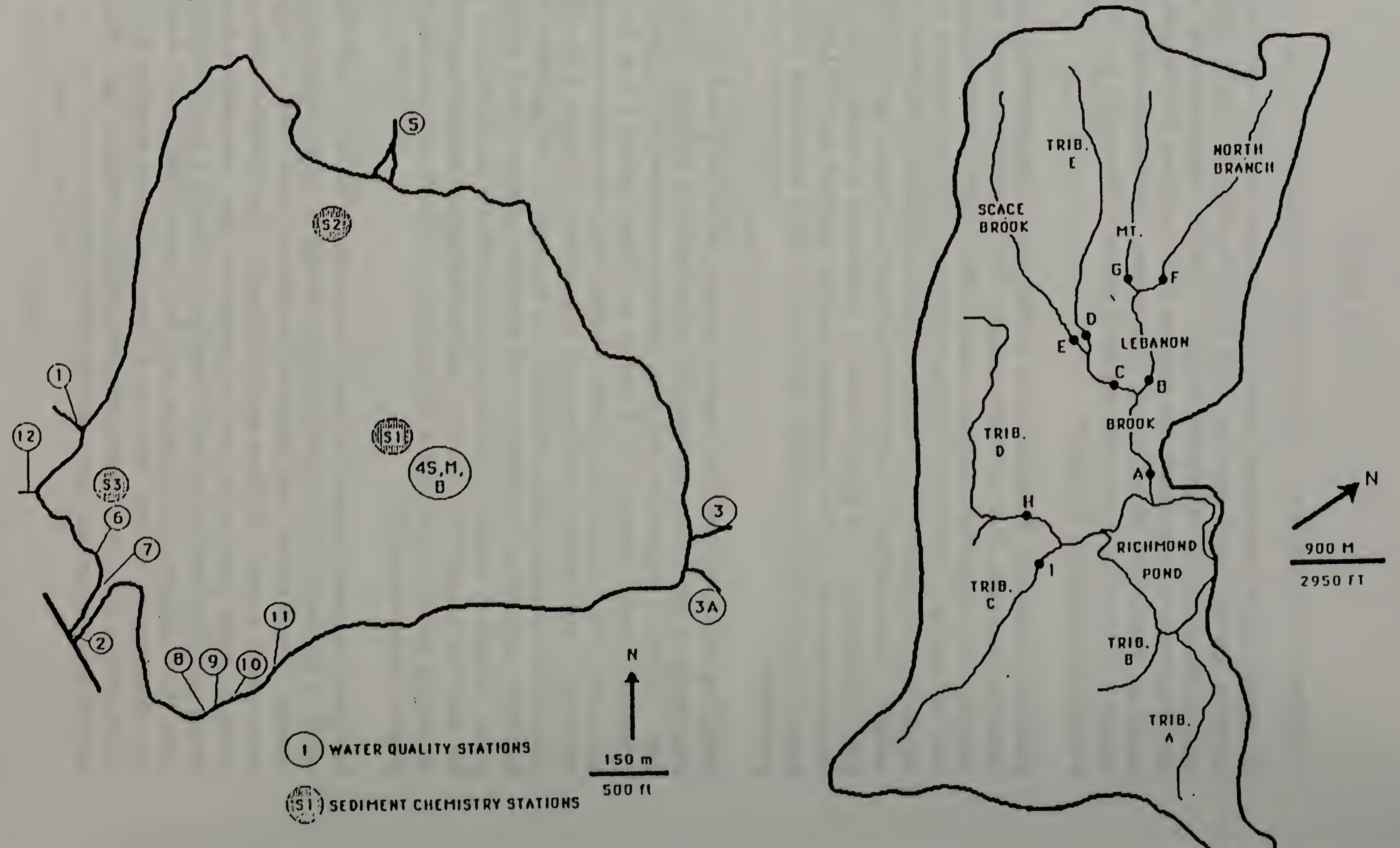
Sampling frequency should be based on quantity of existing data, statistical needs of the study, and perceived rate of change in water quality at points of interest. Water quality was perceived to change rapidly only in response to major storm events. As there was considerable data available from a study about a decade prior to this one, and no before/after comparison was being made, sampling was performed at stations 1 through 5 once during each of June, July, August and September and four more times spread evenly over the remainder of the year. Stations 6 through 12 were sampled during three storm events, and the auxiliary tributary stations were sampled twice, once during dry weather and once during a major storm.

FIGURE 3.5

SAMPLING STATION LAYOUT FOR A DIAGNOSTIC STUDY OF RICHMOND POND

SAMPLING STATIONS FOR THE RICHMOND POND DIAGNOSTIC/FEASIBILITY STUDY

AUXILLIARY SAMPLING STATIONS IN THE RICHMOND POND WATERSHED



Analysis costs vary considerably from lab to lab and with the number of samples collected and number of parameters to be assessed. General analysis cost ranges for a variety of parameters are supplied in Table 3.2. The cost of collecting the samples and interpreting the data have not been factored in; as a rough rule of thumb, assume the total cost of monitoring to be about twice the laboratory analysis cost. If relatively few samples are taken by inexperienced personnel, this will underestimate the cost. If many samples are taken by an experienced crew, this will overestimate the cost. Quality monitoring work is not inexpensive, and consumers should be wary of apparent bargains.

Laboratory turnaround time deserves some consideration in planning a monitoring program. Most labs will provide results almost overnight if paid enough (often double the list price), but a two to three week turnaround time is typical. Different holding times and analysis requirements apply to different parameters, so the turnaround time will most often be a function of the parameter processed the slowest. If some aspect of each sampling depends on the result of the previous sampling, sampling frequency must be lower than the lab turnaround time.

As the flushing rate of most lakes is a matter of weeks or months, particularly during the summer months, water quality changes are apt to be slow in the absence of major storm events. Measurements made only days apart will represent the same water more than those taken weeks apart or months apart. This relation, known as autocorrelation, minimizes the value of frequent sampling unless rapid change in water quality can be documented. Biweekly to monthly sampling is usually sufficient to characterize lake systems, with the potential to assess many parameters on a seasonal basis.

More frequent measures can be pooled to better characterize a period of time, but the value of the data must be weighed against the cost. Parameters which can be assessed with a meter (e.g., oxygen, pH, turbidity) or with inexpensive equipment (e.g., Secchi transparency, flow) are good candidates for daily or weekly assessment by volunteers, as there is little cost beyond the initial capital investment. Statistical analysis of the data for these parameters can be used to infer variability in the data base for less frequently monitored parameters.

Ideally, the study will produce precise, accurate data which can be used to detect significant differences among stations and within a station over time. Precision is the ability to get the same result in repetitive tests with the same sample. Accuracy is the ability to correctly assess the level of a compound in a sample. By sending duplicate samples to the lab periodically and/or by receiving the lab's own quality assurance data, a researcher can assess precision. By sending artificial samples of known composition or again by accepting the lab's own quality control data, the investigator can evaluate accuracy.

As the techniques for most water quality analyses have inherent error, accuracy is sometimes limited. Precision is not limited, however, and is critical to the detection of significant differences among samples. It is important to know at what level the observed difference in the concentration of some pollutant can no longer be a likely consequence of collection or lab error and can be taken as a legitimate difference in water quality. Table 3.5 gives a statistical summary of the results of precision testing of two labs. Results tend to be lab-specific, necessitating the generation of quality control data for each lab with which a researcher deals. Additionally, the results suggest that samples for a given parameter should be sent to the same lab and preferably analyzed by the same technician within a particular study for the best results.

Sampling technique is easier to demonstrate than to write about, but there are some simple guidelines which amount to common sense coupled with some experience. Use appropriate containers, collect a sufficient volume of sample, and carefully label the container with the name of the collecting organization and collector, date, station number, station name, parameters to be assessed, and any preservative used. No preservative is perfect, and the best results are obtained from unpreserved samples processed promptly. As prompt processing is frequently infeasible, pick preservatives appropriately and use multiple, non-interacting preservatives where possible. For example, acidify a sample to be analyzed for nitrogen forms, then keep it on ice in the dark.

Collect samples in a representative manner; do nothing to bias the results. Use composite samples (made from subsamples at multiple locations) where variability over space is apparent, but budget constraints do not allow multiple samples. Do not fail to get an estimate of flow at any inlet or outlet; mass balance budgets cannot be constructed without this information. There are standards for concentrations of many pollutants, but damage can be done without exceeding these standards, and many important parameters have no corresponding standards. Don't come back without the flow data! Finally, keep accurate, organized, legible field notes made at the time of the sampling. Do not try to recall details later. No observation is too trite to be kept out of the field notes; it may prove critical to understanding the data later.

TABLE 3.5

QUALITY CONTROL PROGRAM SAMPLES: SUMMARY STATISTICS

PARAMETER	UNITS	STD.ERR.	AVG%DIF	MAX.VALUE	MIN.VALUE
AMM-N	(mg/l)	.05	56.54	.850	.010
NITRATE-N	(mg/l)	.02	81.76	.550	.010
KNITRO	(mg/l)	.08	54.72	1.650	.250
ORTHO-P	(ug/l)	2.86	35.60	80.000	10.000
TOTAL P	(ug/l)	6.68	54.88	200.000	10.000
FEC.COLI	(#/100ml)	.30	16.67	8.000	2.000
FEC.STREP	(#/100ml)	.38	7.14	8.000	1.000
TALK	(mg/l)	1.42	46.26	21.000	.500
TSS	(mg/l)	1.42	124.76	22.100	.400
CHLORIDE	(mg/l)	1.64	78.45	53.800	2.100

LAB #1 ⇧ ⇩ **LAB #2**

QUALITY CONTROL PROGRAM SAMPLES: SUMMARY STATISTICS

PARAMETER	UNITS	STD.ERR	AVG%DIF	MAX.VALUE	MIN.VALUE
AMM-N	(mg/l)	.004	39.52	.100	.010
NITRATE-N	(mg/l)	.008	47.99	.670	.020
KNITRO	(mg/l)	.014	13.01	.580	.250
ORTHO-P	(ug/l)	.780	10.02	29.000	10.000
TOTAL P	(ug/l)	6.492	43.39	96.000	18.000
FEC.COLI	(#/.1L)	7.662	12.98	250.000	10.000
FEC.STREP	(#/.1L)	738.018	31.66	14000.000	10.000
TALK	(mg/l)	1.552	96.69	22.000	1.850
TSS	(mg/l)	.313	44.71	9.600	.400
CHLORIDE	(mg/l)	1.627	11.49	51.000	18.000

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

Pollutant Loadings and Budgets

Once a data set has been generated, it is useful to compare individual or average values with any available water quality standards. This reveals where the lake stands on some relative scale, and allows classification of the lake. It will not necessarily reveal where to go in terms of management and restoration, however. In order to sort out the various pollutant sources and give them priorities for abatement, it is necessary to construct pollutant loads and budgets. This is analogous to balancing a checkbook, but even more difficult. First one constructs a hydrologic budget, dealing only with the water load, then proceeds to factor in the pollutants of interest which are carried in the water.

Water loads are established by multiplying flows by time. Pollutant loads are established by multiplying concentrations by flows (hence the critical need for flow data), but can be derived in a variety of ways with differing results. For example, the average flow times the average concentration of a pollutant passing a sampling point will be somewhat different than the sum of the result of each flow times each concentration for individual blocks of time represented by individual samples. There are many ways to weight the loading calculation. The key is to choose a method which best represents reality, and clearly document how the method was applied. The use of ranges or application of statistical uncertainty analysis is recommended to allow evaluation of possible error. Aquatic management is an imprecise science; rarely is anyone 100% sure how the system works before taking action. It is important to evaluate all options in light of existing data and variability of those data.

Where empirical data is insufficient to calculate a load, the investigator may resort to various models which will extrapolate from the available information. Export models (Reckhow et al. 1980) involve multiplying land area by an export coefficient representing the amount of pollutant generated per unit area of a given land use. In-lake models allow one to backcalculate an apparent load based on the observed in-lake concentration and knowledge of system hydrology (e.g., volume, rate of flushing, loss of pollutants through settling). In the end, the investigator must usually make judgements or assumptions about what approach best represents the studied system, and these should be carefully documented.

The resulting water and pollutant loads can be organized into budgets for income and outflow, either in tabular (Table 3.6) or graphic (Figure 3.6) form. The inflow and outflow of water is very important to system function, while most pollutant analyses tend to deal mainly with sources of income. From the example budgets in Table 3.6 and Figure 3.6, it is apparent that stormwater flows dominate the hydrology of Buttonwood Pond, conferring considerable instability. A single storm drain contributes a disproportionate amount of the nitrogen and phosphorus entering the pond, making it a logical target of control efforts if nutrient reduction is considered desirable. Other storm drains and waterfowl constitute additional sources which might be controlled. Direct runoff (not through any pipes or tributaries), groundwater, precipitation, and internal recycling appear to be very minor sources of nitrogen and phosphorus in a relative sense. Background (dry weather) inputs of nitrogen from Buttonwood Brook are also relatively large, while phosphorus inputs from this source are small. Management options should be considered in light of their potential impact on these nutrient loads and the resultant effect on lake conditions.

DETERMINING APPROPRIATE LAKE USES

Range of Uses

In a general sense, there are eleven possible uses of lake water:

1. Contact recreation
2. Passive uses/aesthetics
3. Non-power boating
4. Power boating/skiing
5. Fishing
6. Hunting
7. Consumptive supply
8. Power supply
9. Cooling supply
10. Flood control
11. Ice sports

TABLE 3.6

TABULAR HYDROLOGIC AND NUTRIENT BUDGETS

A HYDROLOGIC BUDGET FOR BUTTONWOOD POND

Inputs	cu.m/min	% of Total
Buttonwood Bk. Background	0.70	37.2
Buttonwood Bk. Storm Flow (@Kempton St., Bu-9)	0.51	27.1
36" Storm Drain (Bu-4)	0.45	23.9
All Other Proximal Storm Drains (Bu-5,6,8,14,15)	0.11	5.9
Direct Drainage (Park Lands)	0.03	1.6
Precipitation (Direct Input)	0.05	2.7
Ground Water (Direct Input)	0.03	1.6
Total	1.88	100

Outputs		
Outlet (Bu-3)	1.70	90.4
Evaporation	0.03	1.6
Ground Water	0.15	8.0
Total	1.88	100

Detention Time	Years	Days
Mean	0.02	8.0
Annual Range	<0.001-0.08	<0.1-30
Response Time	0.034-0.057	12-21

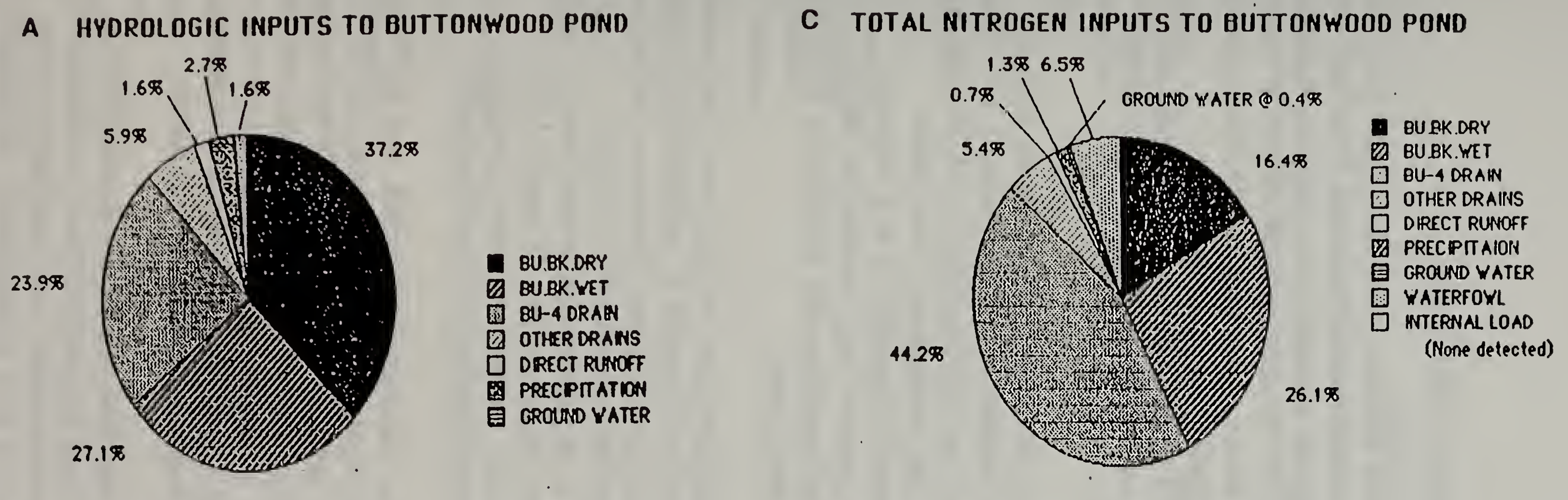
B NUTRIENT LOADS TO BUTTONWOOD POND BASED ON EMPIRICAL DATA AND SELECTED EXPORT COEFFICIENTS

	Total Nitrogen		Total Phosphorus	
Source	kg/yr	% of total	kg/yr	% of total
Buttonwood Bk. Background	504	13.5-19.2	7.4	2.0-3.1
Buttonwood Bk. Storm Flow (@Kempton St., Bu-9)	496-1247	18.9-33.3	31.1-70.0	12.9-19.2
36" Storm Drain (Bu-4)	1258-1520	40.6-47.8	150.4-221.9	61.0-62.3
All Other Proximal Storm Drains (Bu-5,6,8,14,15)	127-230	4.8-6.1	6.9-19.1	2.9-5.2
Direct Drainage (Park Lands)	22	0.6-0.8	0.3	0.1
Precipitation (Direct Input)	41	1.1-1.5	1.0	0.3-0.4
Ground Water (Direct Input)	12	0.3-0.5	1.0	0.3-0.4
Bird Inputs (Direct Input)	170	4.5-6.5	28.3	7.8-11.7
Internal Load (Macrophyte Pumping)	0	0	15.0	4.1-6.2
Total	2630-3746	100	241.4-364.0	100

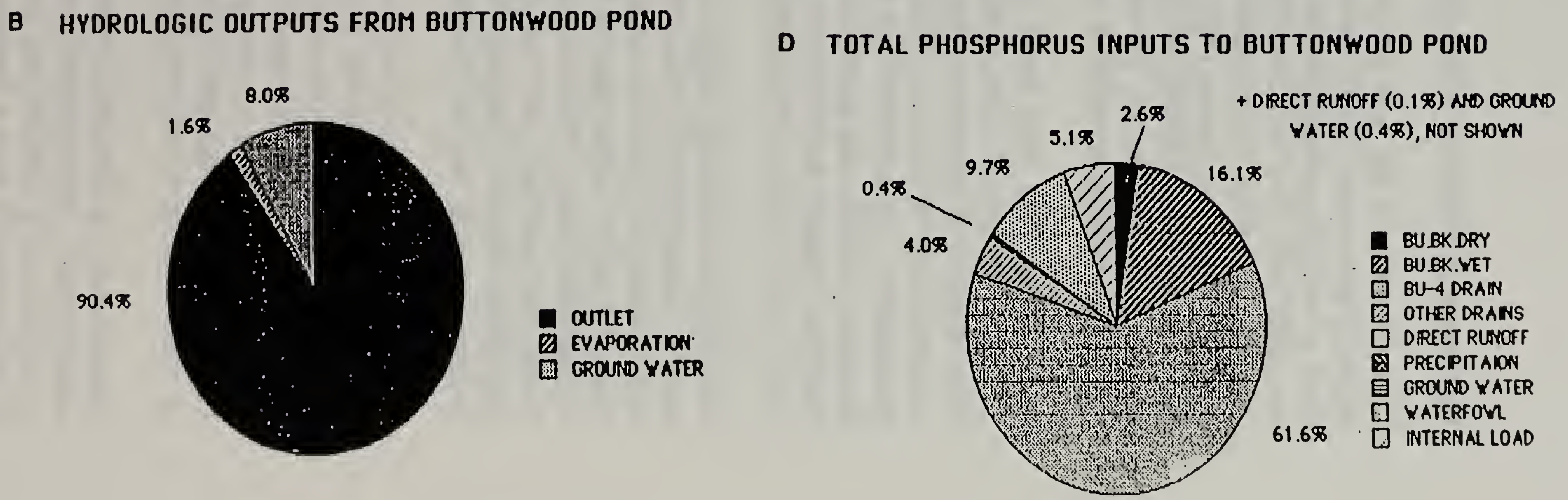
Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

FIGURE 3.6

GRAPHIC HYDROLOGIC AND NUTRIENT BUDGETS


A HYDROLOGIC INPUTS TO BUTTONWOOD POND

C TOTAL NITROGEN INPUTS TO BUTTONWOOD POND


B HYDROLOGIC OUTPUTS FROM BUTTONWOOD POND

D TOTAL PHOSPHORUS INPUTS TO BUTTONWOOD POND

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

Influence of Watershed and Lake Features on Lake Uses

Many aspects of the lake and its watershed influence lake use (Table 3.7). The physical shape and depth characteristics of a lake affect its uses, or at least the level of each use which the lake can support. Greater mean depth is desirable for many uses, but can create safety hazards for contact recreation and winter use. Greater fetch is desirable for many forms of boating, but results in greater wind-induced mixing and turbidity potential. Greater shoreline development (irregularity of shape) tends to increase aesthetic appeal and provides more shoreline for access, but reduces line-of-sight and increases safety hazards for motorized watercraft.

As a general rule, high water clarity (low turbidity) is desirable for all uses, although the best fishing conditions are unlikely to be maintained in a clear lake. Higher dissolved oxygen, lake area, maximum depth, and lake volume are desirable for all uses which have a clear relationship with these parameters. An intermediate pH is generally desirable, as is a balance between panfish and gamefish. Higher levels of toxic substances, fecal bacteria, organic sediments and shoreline dwellings are deleterious to all uses with which a clear relationship can be established.

Macrophyte coverage negatively impacts most uses at high levels and some uses at intermediate levels, but intermediate coverage is beneficial to fishing and aesthetics. Plankton abundance may have indirect benefits to fishing, does not affect winter sports, but negatively impacts other common recreational uses. Plankton abundance is dependent on system fertility and biological structure, and can greatly affect water clarity. Waterfowl can negatively impact consumptive supply and contact recreation through bacterial inputs, but are desirable for many passive uses and aesthetics.

Detention time, watershed:lake area ratio, land use and slopes, and soil types have a variety of potential positive and negative impacts. Effects are primarily related to how much water of what quality is delivered to the lake, and can be positive or negative depending upon the lake use considered. For most recreational or consumptive uses, a constant and substantial throughflow of high quality water from a relatively undeveloped watershed is preferable, but such conditions are relatively rare in Massachusetts.

Features of the lake and its watershed therefore predispose a lake toward certain uses. Management can adjust some features to create conditions more conducive to a desired use, but there are reasonable and practicable limits. It is often wise to take a regional approach to lake management, emphasizing the best use for each lake yet providing a diversity of uses and recreational

TABLE 3.7

EFFECTS OF LAKE AND WATERSHED FEATURES ON LAKE USES

(++ = Direct positive relation, + = Indirect positive relation, — = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g, bell curve)

	LAKE USE						
LAKE FEATURES	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Water clarity	++	++	++	++	++	-	0
Dissolved oxygen	+	+	+	0	0	++	0
Temperature	0	++	0	++	++	*	-
pH	*	*	*	0	0	*	0
Fertility	-	-	*	-	-	+	0
Toxic substances	—	—	-	-	-	—	0
Fecal bacteria	—	—	0	-	-	0	0
Macrophyte cover	-	—	*	—	—	*	0
Plankton abundance	--	—	--	-	-	+	0
Panfish abundance	-	-	*	0	0	++	0
Gamefish abundance	+	+	+	0	0	++	0
Waterfowl	-	-	*	0	0	0	0
Lake area	+	++	0	++	++	++	++
Mean depth	+	-	0	0	++	0	-
Maximum depth	+	0	0	0	0	+	0
Lake volume	++	0	0	0	0	+	0
Fetch	-	-	0	*	++	0	+
Shoreline development	0	+	++	+	-	0	*
Detention time	—	*	*	0	0	0	+
Organic hydrosoils	-	-	0	0	0	0	0
WATERSHED FEATURES							
Watershed:lake area ratio	*	-	-	0	0	0	0
Access to lake	-	++	*	*	*	*	++
Shoreline dwellings	-	-	--	0	-	0	0
Soil permeability	*	+	+	0	0	0	0
Land slopes	*	-	0	0	0	0	0
Urbanization	-	-	—	0	0	-	-
Agriculture	-	-	—	0	0	*	0
Logging	*	-	—	0	0	0	0
Hardwood:softwood ratio	*	0	0	0	0	0	0

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

experiences within a finite geographic area. One park lake may be managed for swimming, while another is used primarily for boating and yet another for fishing. Additional uses may be possible in each, but management will be slanted toward the designated primary use.

Influence of Lake Uses on Lake Features

Lake uses tend not to influence the ecology of a watershed, although its economic well-being may be clearly affected. Lake uses can affect certain lake features, however, in a set of feedback loops which affect uses and require management (Table 3.8). Contact recreation can reduce water clarity and macrophyte coverage on a localized level, and power boating can do the same on a more widespread scale. Passive uses, non-power boating, and on-ice activities tend to have minimal influence, if responsibly carried out. Consumptive supply uses can affect system ecology and features through the impact of fluctuating water levels.

Influence of Lake Uses on Other Lake Uses

Interactions between lake uses encompasses the user conflicts discussed previously. Almost no lake use affects other lake uses in a positive manner (Table 3.9); many lake uses have no clear relation, and some negative impacts are indirect, but it is apparent that single use lake management would yield the least complications. Multi-use management is nearly always mandated, however, except where risks to potable supply greatly outweigh the perceived benefits of recreational pursuits. Such is rarely the case in Massachusetts, and we find extensive recreational use of many reservoir facilities, including the Quabbin system. As a consequence, user conflicts are inevitable, and effective management requires a clear set of priorities and procedures to succeed.

Establishing Priorities

Three steps are necessary in this process:

1. Assessing the reasonable/practicable uses of the lake, based on lake and watershed features
2. Assessing the needs and desires of the user populations, including non-human elements
3. Building concensus toward an acceptable priority of uses and management framework

TABLE 3.8

EFFECTS OF LAKE USES ON LAKE FEATURES

(++ = Direct positive relation, + = Indirect positive relation, -- = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g. bell curve)

	LAKE USE						
LAKE FEATURES	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Water clarity	0	--	0	0	--	0	0
Dissolved oxygen	0	0	0	0	0	0	0
Temperature	0	0	0	0	0	0	0
pH	0	0	0	0	0	0	0
Fertility	0	0	0	0	0	0	0
Toxic substances	0	0	0	0	++	0	0
Fecal bacteria	0	+	0	0	0	0	0
Macrophyte cover	0	--	0	0	*	0	0
Plankton abundance	0	0	0	0	0	*	0
Panfish abundance	0	0	0	0	0	+	0
Gamefish abundance	0	0	0	0	0	--	0
Waterfowl	0	0	0	0	--	0	0
Lake area	--	0	0	0	0	0	0
Mean depth	--	0	0	0	0	0	0
Maximum depth	--	0	0	0	0	0	0
Lake volume	--	0	0	0	0	0	0
Fetch	--	0	0	0	0	0	0
Shoreline development	0	0	0	0	0	0	0
Detention time	--	0	0	0	0	0	0
Organic hydrosoils	0	0	0	0	0	0	0

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.9

EFFECTS OF LAKE USES ON OTHER LAKE USES

(++ = Direct positive relation, + = Indirect positive relation, -- = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g, bell curve)

(All effects are read as the effect of the vertically listed (Y-axis) use on the horizontally listed (X-axis) use)

	LAKE USE						
LAKE USE	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Consumptive Supply	X	-	-	-	-	*	-
Contact Recreation	--	X	-	--	--	--	0
Passive Uses + Aesthetics	0	0	X	0	0	0	0
Non-power Boating	-	--	-	X	-	-	0
Power Boating	-	--	-	--	X	-	0
Fishing	0	--	0	0	0	X	-
Ice Skating and Boating	-	-	*	-	-	0	X

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

As mentioned previously, this is best accomplished from a regional perspective. It would seem foolish to attempt to establish power boating and waterskiing in a shallow lake loaded with stumps when there is a large, deep lake nearby. It is not logical to turn a heavily used pond within the flyway of major waterfowl migrations into a potable water supply facility. On the other hand, it is important to consider the demand for various uses within an area, and to try to satisfy that demand in a rational manner.

The tough part is building a concensus; fish and waterfowl do not vote in most towns, laws that protect wetlands and water quality rarely consider recreational use demand, and lake users frequently fall into tightly defined special interest groups (i.e., user categories like swimmers, boaters, or anglers). The Delphi process (Delbecq et al. 1975) is an iterative process for achieving concensus within a group selected to represent a cross section of users and managers, and is often more successful than large scale user surveys or town/regional meetings. In any process, it is critical to supply accurate, unbiased information to all concerned parties and to listen carefully to their perspective on the relevant issues.

Rest assured that when all is said and done and a management plan is put in place, you will hear little from those satisfied and a lot from dissatisfied users, many of whom declined to participate in the concensus building process. The whole process of management should have some flexibility built into it, such that adjustments can be made when new information becomes available or use demand is altered. Yet the manager cannot spend all his or her time oiling the "squeaky wheels"; it is essential to maintain a clear focus on the management goals and priorities.

POST-TREATMENT MONITORING

Proper post-treatment monitoring will vary greatly with the treatment employed and the results desired. Presumably, the most sought-after improvements will be greater water clarity or lower aquatic plant density. In these cases, Secchi transparency and cover by plants (as percent cover and/or biomass per unit area for each species) are the preferred monitoring parameters. Additional parameters of interest will include phosphorus, nitrogen, dissolved oxygen, pH and characterization of the phytoplankton, fish and invertebrate communities, but managers should be careful not to overextend a limited budget. It is best to select a few parameters which adequately characterize management progress and to monitor these parameters at appropriate intervals.

Monitoring frequency will vary from around once every two weeks for Secchi transparency to once every year or two for the fish community. For most chemical parameters, monthly measurement is adequate, while seasonal measurement is appropriate for plankton. Rooted plant density should be assessed at least annually and preferably twice per year, in late spring and late summer.

The selection of parameters will also be dependent upon the pre-treatment data. Adequate pre-treatment data is essential to a valid before-after comparison, and consistency of methods in each project phase is necessary. If one form of phosphorus was measured before an alum treatment. Other forms may be added for an improved interpretation of results, but the original form cannot be dropped if a valid before-after comparison is to be made.

If reduced loading of a given pollutant is anticipated, flow will need to be monitored to allow an evaluation of changes in loading. Even if the pollutant concentration is assessed only once per month, more frequent flow measurement is desirable. Flows can be highly variable, but it is inexpensive to quantify this variation. Dry and wet weather measurements are necessary.

Where the treatment has a drastic effect on the environment (e.g., dredging, chemical treatment, harvesting), effects should be detectable immediately, but several years may be necessary for the system to reach a new equilibrium, if one is indeed reached. A three-year post treatment monitoring program is advisable in nearly all cases, with some degree of monitoring warranted on an ongoing basis in most cases. What is typically a relatively small monitoring cost is nearly always warranted to protect the investment made through management.

Where the treatment is expected to gradually change the system through reduced pollutant loading (most watershed-based techniques) or biomanipulation (e.g., fish stocking, selective planting), it is critical to allow enough time to make valid statistical comparison. Where slow changes are involved, natural variability (dry years vs. wet years, for instance) may overshadow the change in any given year, necessitating multiple years of monitoring. The human eye rarely detects any change in water clarity below an actual change of 20%, and a statistical test for changes of less than 20% is likely to require tens of data points. As spacing these points too close together in time can destroy the statistical validity of the comparison, several years of data are generally required for a valid assessment.

Not all changes require statistical verification, however. User perceptions or simple photographs are often sufficient to assess project progress. It could take a very expensive monitoring program to assess the effect of fish stocking on fish size structure and angling success. It may be easier and more appropriate to simply interview fishermen before and after stocking to record their impressions and satisfaction level. The level of stocking should be adjusted to meet demand within ecological reason, as opposed to achieving some less tangible size structure goal.

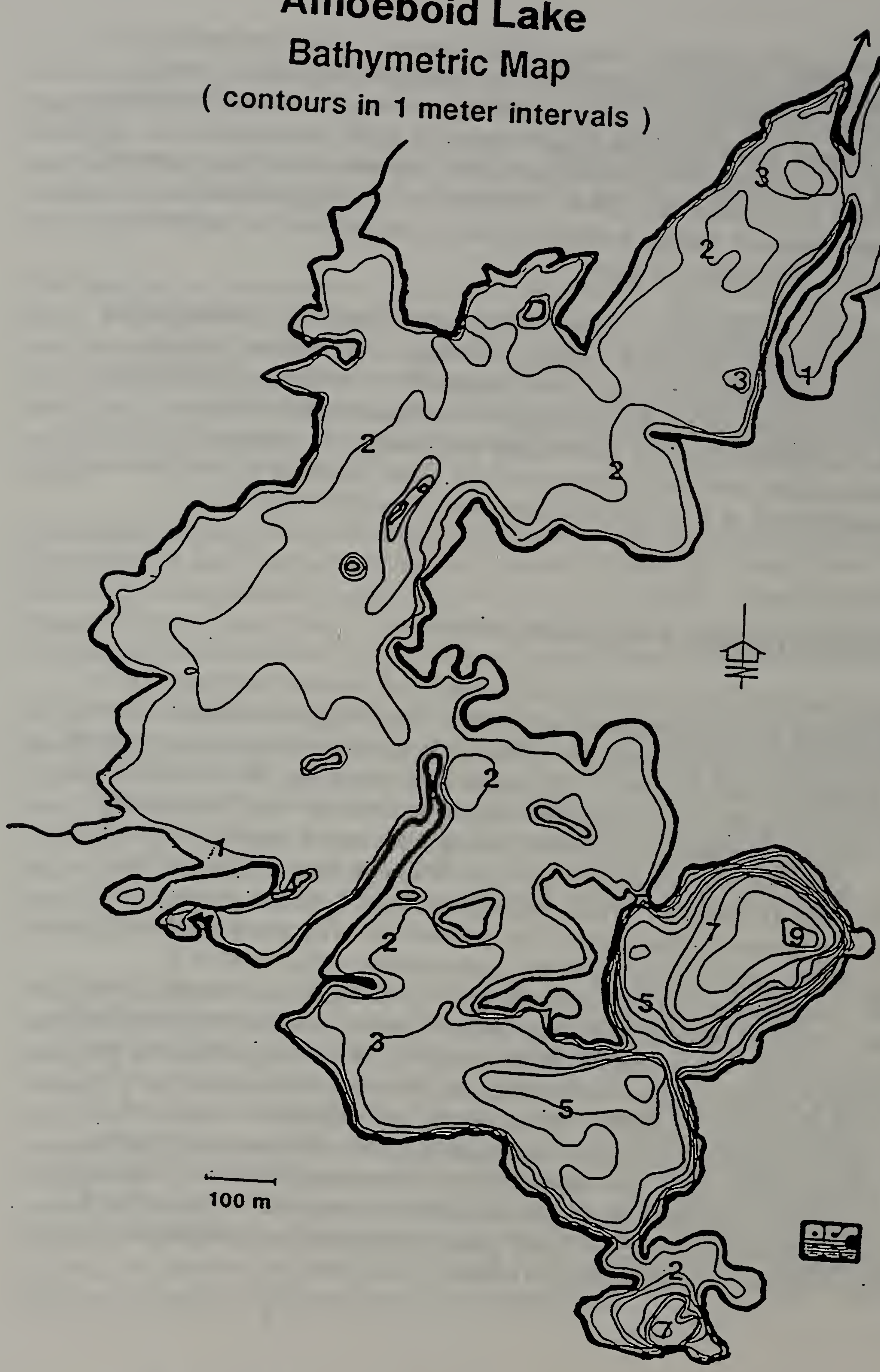
Tailoring a monitoring program to meet the specific needs of a management program can be challenging and at times frustrating. Professional help is advisable, particularly when setting up the program. It is highly desirable to enter a treatment phase with a standardized set of measurements and a framework for comparison which needs only the data to be complete. A proper post-treatment monitoring program will allow charting of progress as well as documentation of goal achievement, and is well worth the investment.

MINI-TEST: MONITORING PROGRAM DESIGN

It is the end of the fiscal year, and $50,000 is left in an account and must be spent. Complaints from swimmers about weed infestations and algal blooms in Amoeboid Lake have prompted the DEM to devote the money to a study of the lake to determine the level of the problem and its impact on lake uses. A bathymetric map (Figure 3.7) is available from the Division of Fisheries and Wildlife, as this is a popular warmwater fishing lake and is stocked with trout each spring. A map of the watershed and sub-drainage basins (Figure 3.8) is available from the Division of Water Pollution Control, which prepared a preliminary assessment of the lake and its watershed. There are no direct entry storm drains, and the inputs from precipitation, tributaries and groundwater seepage result in an average hydraulic residence time of almost five months. The lake bottom is mainly organic muck, with gravel/sand bars protruding in shallow wave-washed areas. Much of the watershed land was at one time agricultural, became reforested, and is now being rapidly urbanized. The soils are primarily well drained, but slopes are steep and vegetative cover is lacking in many construction areas. Main access points consist of a public boat ramp and several large but private beaches. There are numerous shoreline cottages, many converted from seasonal to year-round use. Nothing is known of specific water quality, but most complaints site low water clarity, high color, and detectable odor.

FIGURE 3.7

Amoeboid Lake
Bathymetric Map
(contours in 1 meter intervals)



Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

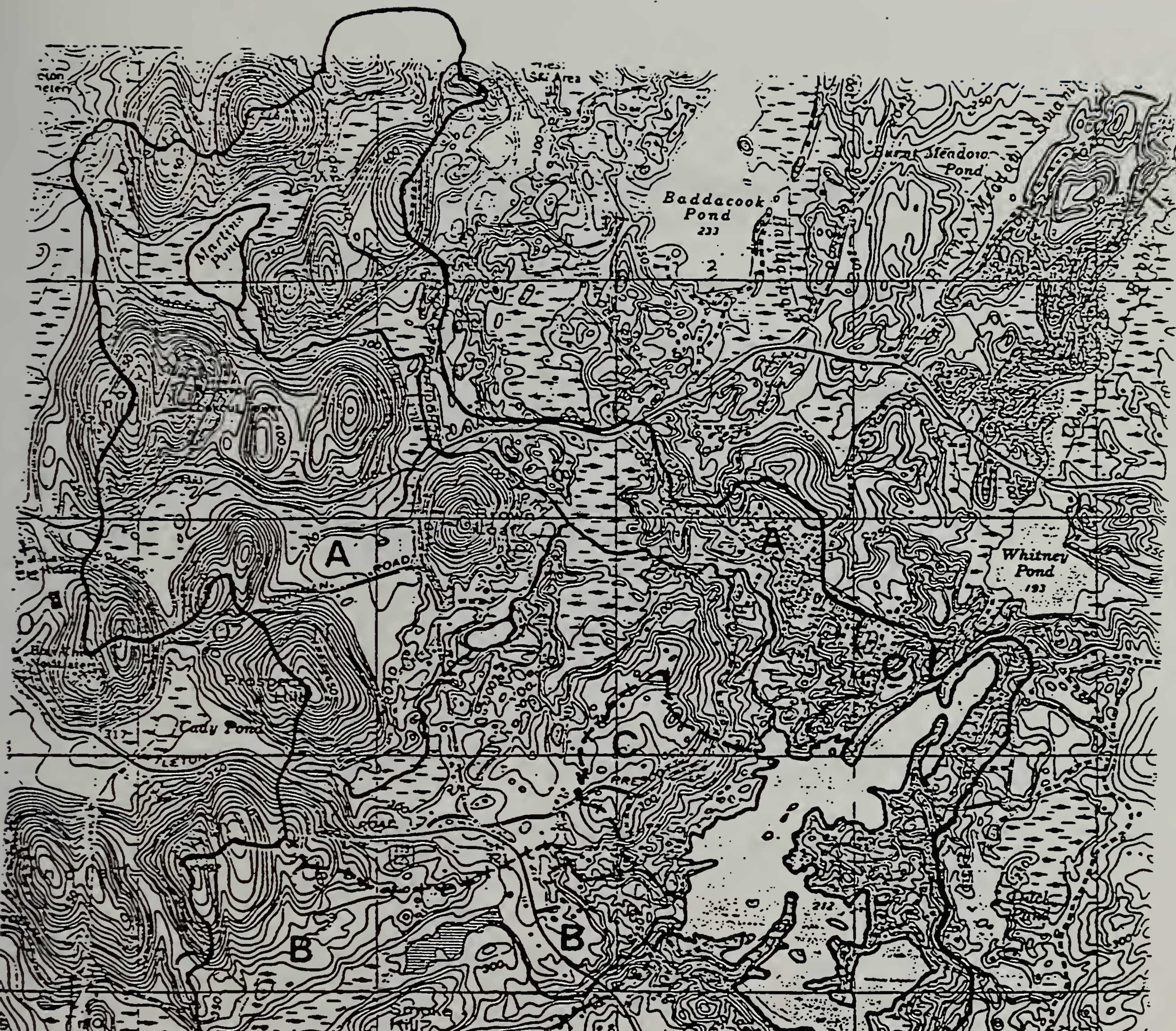


FIGURE 3.8

WATERSHED OF AMOEBOID LAKE

Sub-Drainage Basins.

A = Martin's Pond Brook.

B = Unnamed tributary.

C = Direct drainage.

Scale = 1 : 25,000

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

1. From the information provided, what can you discern about the suitability of this lake for various uses?

2. What parameters will be of prime interest in the study?

3. What stations would you select for repeated assessment of water quality?

4. How often would you sample these stations?

5. With the budget provided and the information on costs provided in Table 3.2, design a diagnostic study which yields the information necessary to define the problems and assess their impacts. Is there enough money? If not, which aspects of the study should have top priority?

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SECTION 4.

LAKE AND WATERSHED MANAGEMENT

LECTURE OUTLINE

SECTION 4: LAKE MANAGEMENT AND WATERSHED MANAGEMENT

1. IN-LAKE MANAGEMENT TECHNIQUES

a. Physical Techniques

- Benthic Screening
- Lake Level Drawdown
- Dredging
- Harvesting
- Hydroraking
- Aeration
- Hypolimnetic Aeration
- Hypolimnetic Withdrawal
- Sediment Oxidation
- Dilution and Flushing
- Artificial Circulation

b. Biological Techniques

- Grass Carp
- Pathogens
- Insect Pests
- Food Chain Manipulation

c. Chemical Techniques

- Herbicides and Algicides
- Alum
- Dye

2. WATERSHED MANAGEMENT LECTURE

Community vs. Site Level Controls
- When applicable

a. **Regulatory Controls**

- Role of zoning, subdivision, health and wetland regulations
- What regulatory controls are applicable to DEM practices?

Zoning - What tools are available? When are they applicable?

1. Overlay Districts
2. Use Prohibition
3. Special Permitting
4. Large Lot Zoning
5. Site Plan Review
6. Waterway Buffers
7. Transfer of Development Rights
8. Cluster
9. Growth Controls/Timing

Subdivision Rules and Regulations-Site Level Controls

1. Drainage Requirements
2. Performance Standards/Nutrient Loading

Health Regulations

1. Underground Fuel Storage Systems
2. Small Sewage Treatment Plants
3. Viral Buffer Zone
4. Septic Cleaner Ban
5. Septic System Maintenance
6. Sewage System Upgrades

Wetland Regulations

1. Waterway Buffers

b. **Legislative Techniques**

- Current legislation concerning lakes and their tributaries

1. Lake Wauchusett Bill
2. Riverways Protection
3. Phosphate Ban

c. **Park/DEM Watershed Management Techniques**

- Use of site design techniques and goals program to lessen watershed impacts

  1. Site Design
  2. Monitoring
  3. Public Education
  4. Use Controls
  5. Park Planning/Goals Program
  6. DEM-Community Coordination
  7. DEM Training

3. PERMIT REQUIREMENTS FOR TYPICAL RESTORATION PLANS

a. **Introduction**
b. **Permits Required for Typical Restoration and Maintenance Programs**

- Local
  1. Conservation Commission
  2. Board of Health

- State
  1. Department of Environmental Protection

     a. Division of Wetlands and Waterways
     b. Division of Water Pollution Control
     c. Division of Solid Waste Management

  2. Department of Fisheries, Wildlife and Environmental Law Enforcement

     a. Division of Fisheries and Wildlife
     b. Natural Heritage and Endangered Species Program

  3. Massachusetts Coastal Zone Management Office
  4. Massachusetts Historical Commission

    5. Department of Environmental Management
    6. Massachusetts Environmental Policy Act Unit
    7. Department of Food and Agriculture
    8. Metropolitan District Commission
    9. Department of Environmental Protection
       Board of Water Commissioners
    10. Other state permits that may apply for major Lake Remediation Projects

- Federal
    1. Army Corps of Engineers
    2. Environmental Protection Agency

c. **Permits Required for Watershed Management**
d. **Regulatory Interactions**

Lake And Watershed Management

Lake management methods may be divided into in-lake and watershed controls. For the purposes of this section, the term watershed will include the surface watershed and ground-water recharge areas. Choice of a method depends upon the site-specific characteristics of each lake, as well as its cost and availability, aesthetics, and personal preferences. Each control method is appropriate to a particular set of circumstances. For example, controlled drawdown of lake levels is one possible method used to manage plant growth. Drawdown exposes littoral plant colonies during freeze-thaw periods and can be an effective control. However, drawdown is not an option for lakes where only limited drawdown is possible or where drawdown may result in the loss of valuable plant and animal species. Therefore, the particular characteristics of each site must be considered when selecting a remediation method.

Typically a combination of both in-lake and watershed measures provides the most effective strategy. Treating the in-lake symptoms does not necessarily rid a lake of its problems, since the cause of the problem may be in the watershed. Likewise, treating the cause of the problem in the watershed may eliminate the in-lake symptoms. For example, nutrient fluxes from sediments within the lake may be sufficient to maintain eutrophic conditions, even after minimizing nutrient loading from the watershed.

Typical lake remediation and watershed protection measures will be presented in this section of the course.

NECESSARY EXPERTISE

The in-lake and watershed management strategies and permitting requirements to be discussed require a range of scientific and planning expertise. Scientific knowledge of in-lake and watershed functions and impacts is needed to assess the existing conditions in a lake and its watershed, and to determine the causes of a lake problem. Once this information is obtained, the biological, economic and political ramifications of the various management strategies must be weighed, before a successful management strategy is developed. Once a management strategy is developed, necessary permits must be obtained.

IN-LAKE MANAGEMENT TECHNIQUES

In-Lake Management of Lakes and Ponds

The long-term management of a lake or pond can be likened to the maintenance of a person's body. To remain healthy the lake needs to receive nutrients in appropriate quantities. Excessive nutrient loading, like overeating, leads to an accumulation of excess biomass and potential health problems. In the case of the lake, the biomass accumulates in the form of excessive algal growth or very dense concentrations of aquatic weeds. This excessive plant growth, in turn, reduces the health of the lake. For example, excessive weed growth can cause stunted fish and reduce the recreational uses of a lake or pond.

As with overeating, the best way to solve lake problems is to reduce the input. Most long-range methods of lake management try to redress excessive nutrient inputs by attacking the problem at the source--the watershed. However, it is often expensive and difficult to manage the watershed. Even if the watershed is managed in-lake management techniques are often necessary. The following discussion deals with various methods of in-lake management.

Several techniques can be used to manage plant growth in lakes and ponds. The ideal management method for aquatic weeds would be species-specific (i.e., affecting only those species that constitute pests) and site-specific (i.e., affecting only those areas where weeds had become problematic. The ideal method should also be safe and applicable to all areas where plants become a nuisance. It should not adversely affect the environment or human health. Lastly, it should be low-cost and long-lived. Obtaining these goals is very difficult and often impossible.

An evaluation and understanding of the negative and beneficial aspects of the various techniques must be understood before implementing any management program. Choosing a management program depends on the pros and cons of the available methods, and on local constraints and desires as well as biological-chemical characteristics of the lake. Thus, decisions about lake management should be made by local residents in consultation with a limnologist or person trained in lake/pond management.

The following is a short description of in-lake management techniques together with the benefits, detriments and costs. Table 4.1 presents the impacts of the in-lake management techniques discussed.

Physical Techniques

Benthic Screening

There are various methods of screening off aquatic plant growth with physical barriers such as benthic (plastic) screening or sand. These screens physically block the growth of macrophytes in target areas.

Cost

The cost usually ranges from $500 to $5,000 per acre.

Benefits

- Aquatic plants can be excluded if the weed beds are covered in early spring.
- This method is site specific. Only those areas that are treated are affected.

Detriments

- It is difficult to place and maintain the benthic screening in specific areas.
- Plants can send shoots or root systems to the edge of the screen and grow quite successfully around the edge of the screen. If any cracks, tears, or openings of the screen occur, plant growth will thrive in these areas.
- Benthic screens must, in almost all instances, be picked up, cleaned and replaced every one to three years, otherwise plants will begin to grow on sediments deposited on top of the screens.
- Benthic screening adversely affects benthic organisms, including bottom feeding and bottom spawning fish populations.
- The method is non-specific with regard to plant species. It affects beneficial species of vegetation as well as nuisance species.

TABLE 4.1 IN-LAKE MANAGEMENT DECISION SELECTOR

This form is intended to aid in the evaluation of a particular management technique.

PREPARED BY LEE LYMAN

LYCOTT ENVIRONMENTAL RESEARCH, INC

CATAGORY	DREDGE		DRAWDOWN FLUSHINO		AERATION		HERBICIDE		ALGAECIDE		HARVEST		HYDRO-RAKE		SEDIMENT TILLINO		HYPO-LIM WITHDRAWEL	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
OUTLET STRUCTURE ADEQUATE	5		10		1		3		3		1		1		1		8	
PRIVATE WELLS	10		10		1		6		4		2		2		2		1	
ASSOCIATED WETLANDS	9		8		1		2		1		1		3		1		1	
IMPACTS TO FISHERIES	10		8		7		3		2		8		10		10		8	
AMPHIBIANS	10		9		1		1		1		6		8		6		1	
MUSSELS	10		10		3		1		1		1		10		10		2	
CRAWFISH	10		8		1		1		1		1		10		10		1	
BENTHICS	10		10		1		2		4		3		10		10		2	
WATER FOWL	10		6		1		1		1		1		3		1		1	
PUBLIC DRINKINO WATER SUPPLIES	10		8		1		10		10		5		5		5		1	
HYDROLOGY BUDGET	10		10		1		8		6		2		2		2		8	
EXPOSURE OF MOST AQUATIC PLANTS	8		10		1		8		1		8		8		8		1	
DISRUPTION OF RECREATIONAL ACTIVITIES	10		10		1		4		3		3		4		1		1	
IMPACTS TO NON-TARGET ORGANISMS	10		8		1		2		3		5		10		10		1	
SELECTIVITY FOR SPECIFIC AREAS OF POND	1		2		1		10		1		8		10		10		1	
SPECIES SPECIFIC	1		1		1		9		9		2		4		1		1	
LONGTERM EFFECTIVENESS	5		10		3		6		2		1		4		2		4	
TYPE OF POND BOTTOM	10		8		1		1		1		8		10		10		2	
DOWN STREAM EFFECTS	10		8		1		2		2		2		2		1		4	
AGRICULTURAL USE	10		8		1		10		8		1		2		2		8	
PERMITTINO	10		5		2		8		7		3		3		4		2	
CONSERVATION COMMISSION	10		10		1		10		10		10		10		10		5	
DEP																		
LAKES PERMIT/LICENSE	1		10		1		10		10		1		1		1		1	
DIV WATERWAYS	10		1		1		1		1		1		1		5		1	
WATER QUALITY CERTIFICATE	10		1		1		1		1		1		1		5		5	
WETLANDS	10		10		1		8		10		10		10		10		1	
PESTICIDE BOARD LICENSE	1		1		1		10		1		1		1		1		1	
ARMY CORPS OF ENGINEERS	10		1		1		1		1		1		1		1		1	
FISHERIES & WILDLIFE	10		10		5		1		1		1		1		1		1	
MEPA	10		2		1		1		1		1		1		1		1	
COST HIGH (H), MODERATE (M), LOW (L)																		
INITIAL	H		M		H		M		L		M		H		H		H	
ANNUAL	L		L		M		M		L		M		M		M		L	
PER ACRE	H		L		H		L		L		M		M		M		M	

CATAGORY	BENTHIC SCREEN		SEDIMENT OXIDATION		BIOLOGICAL		ALUM		DYE		DILUTION		ARTIFICIAL - CIRCULATION		FOOD CHAIN MANIPULATION	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
OUTLET STRUCTURE ADEQUATE	1		1		9		3		10		5		5		1	
PRIVATE WELLS	1		1		1		1		7		1		1		1	
ASSOCIATED WETLANDS	1		1		2		1		1		1		3		1	
IMPACTS TO FISHERIES	8		8		10		3		2		8		10		10	
AMPHIBIANS	6		1		6		1		1		2		10		3	
MUSSELS	10		10		2		1		1		4		10		2	
CRAWFISH	10		8		7		1		1		4		10		3	
BENTHICS	10		10		8		1		1		7		10		3	
WATER FOWL	1		1		1		1		1		1		2		1	
PUBLIC DRINKINO WATER SUPPLIES	1		5		3		1		1		1		1		1	
HYDROLOGY BUDGET	1		2		2		10		10		10		1		1	
EXPOSURE OF MOST AQUATIC PLANTS	8		1		8		1		1		1		2		1	
DISRUPTION OF RECREATIONAL ACTIVITIES	1		1		5		2		1		3		5		1	
IMPACTS TO NON-TARGET ORGANISMS	10		10		8		1		1		4		10		5	
SELECTIVITY FOR SPECIFIC AREAS OF POND	10		1		1		1		1		1		10		1	
SPECIES SPECIFIC	1		1		4		9		1		1		1		4	
LONGTERM EFFECTIVENESS	2		2		8		6		1		8		3		5	
TYPE OF POND BOTTOM	10		10		2		1		1		1		10		2	
DOWN STREAM EFFECTS	1		2		4		1		10		10		5		3	
AGRICULTURAL USE	1		2		3		1		3		5		1		2	
PERMITTINO	1		3		10		2		6		5		3		4	
CONSERVATION COMMISSION	10		10		10		10		10		10		10		2	
DEP																
LAKES PERMIT/LICENSE	10		1		1		10		10		1		1		1	
DIV WATERWAYS	1		1		1		1		1		10		1		1	
WATER QUALITY CERTIFICATE	1		1		1		1		1		10		1		1	
WETLANDS	10		1		10		10		10		5		1		1	
PESTICIDE BOARD LICENSE	1		1		1		10		10		1		1		1	
ARMY CORPS OF ENGINEERS	1		1		1		1		1		1		1		1	
FISHERIES & WILDLIFE	1		1		10		1		1		5		1		10	
MEPA	1		1		1		1		1		1		1		1	
COST HIGH (H), MODERATE (M), LOW (L)																
INITIAL	H		H		M		M		H		H		H		M	
ANNUAL	H		H		M		M		H		M		H		L	
PER ACRE	H		H		M		L		H		M		H		L	

NOTE: • "1" IS NOT APPLICABLE OR SIGNIFICANT. "10" IS HIGHLY APPLICABLE OR SIGNIFICANT.

• THE COLUMN "G", IS A GENERAL EVALUATION DEVELOPED BY LEE LYMAN BASED ON 25 YEARS OF EXPERIENCE

• THE COLUMN "S", IS INTENDED TO BE FILLED OUT BY THE USER FOR A SPECIFIC LAKE.

Long-Term Effects

If the installers are vigilant about maintaining and cleaning the screen, it can be effective for many years in managing aquatic plants.

Lake Level Drawdown

Description

Lake level drawdown can be an effective way to manage nuisance growths of aquatic plants. Drawdown also offers local residents an opportunity to rehabilitate near- shore areas and docks as well as reversing the eutrophication of a lake.

Cost

Drawdown is usually the least expensive method for aquatic weed management. However, it can be costly if the dam or outlet structure needs to be reconstructed and/or nearby private wells need to be deepened.

Benefits

- Management of weeds is accomplished by disrupting the sediments and not by freezing. Disruption of the sediments through the following actions precludes most aquatic vegetative growth.

    1. Compaction of sediments.
    2. Migration of silty organic matter to the pond/lake center via rain and its associated erosion.
    3. Freeze-thaw cycles disrupt the sediments, bringing rocks, boulders and stones migrating upward in the exposed sediment and sending the finer, nutrient-rich particles downward into the deep sediments.
    4. Drying and subsequent aeration of sediments aids in release of nutrients.

The pond/lake's water level may be restored during early January. If the sediments are frozen at this time, they will be severely disrupted if the water level rises quickly. Since ice floats, the frozen sediment layer is often literally torn from the bottom as the water rises. These sediments will drop back to the bottom in a matter of two to three days due to the absorption of sun light. Home owners and pond/lake residents can clean out their shoreline areas by raking.

Detriments

- Only certain bodies of water are conducive to lake level drawdown (in many lakes water levels cannot be controlled).
- Only those sediments that are exposed to the disruptive activities during the Fall and Winter will produce negative effects on the rooted aquatic plant growth. If all the above outlined disruptive activities occur to the exposed sediments, all rooted macrophytes will be affected, other than the emergent plants associated with bordering vegetated wetlands. Aquatic vegetation growing in the area below the water's level during drawdown will not be adversely affected.
- Amphibians and other aquatic fauna that use the mud for hibernation can be killed during drawdown. (This impact can be greatly reduced if drawdown is done before animals hibernate.)
- If private or public drinking water supplies rely on the head pressure of the pond/lake's water, these wells may go dry.
- Aesthetically, the bottom of the pond/lake, especially during the Fall, is not very pleasing.
- Odors, such as hydrogen sulfide, can be produced during the drying out of the sediments in the Fall.
- Adverse effects on associated wetlands must be evaluated and mitigated.
- Possible passage of high turbidity from lakes to downstream water resources.
- Possible fish kills of winter population.

- Possible impairment of production wells.

- Possible downstream flooding during drawdown.

- Restoration of water level in January may disrupt any ice related sports.

Dredging

Description

There are two methods for removing sediments from a lake or pond: draining the lake and conducting dry dredging or by removing sediments under water (so called wet- dredging.) Wet dredging can be more expensive and may require more extensive de-watering and holding ponds.

Cost

Dredging costs between $5.00 and $25.00 per cubic yard depending upon the size of the project. In New England, dry dredging typically costs $5.00 to $12.00/cubic yard, while wet dredging usually costs $8.00 to $15.00/cubic yard. However, costs are highly site specific, and should not be estimated through $/cubic yards methods. Assuming, for illustration, that the sediment depth averages 1 yard, costs might range from $40,000 to $100,000 per acre. Dry dredging costs can range between $0 to $10.00 per cubic yard. There have been a few occasions when ponds or sections of lakes/ponds have been dredged and the contractor removing the sediment has paid the lake association, town, or local agency for the material.

Benefits

- Increasing the depth of shallow lakes has long-term advantages. Adequate depth promotes fish growth, discourages weed growth, lowers water temperatures, increases oxygen levels, and recreational boating opportunities.

- Dredging can effectively remove plants, organic matter and nutrients. The removal of nutrients and sediment will reduce the internal nutrient loading, and help to discourage further growth of algae and weeds.

- Site specific, it can be directed at target areas.

Detriments

- Dredging may temporarily displace or kill some of the living organisms including fish and benthics in the pond/lake.
- Dredging temporarily disrupts reproduction of aquatic fauna.
- Portions of the use of the pond/lake for human activities are precluded during dredging.
- Disposal of the dredged spoils is costly and may pose environmental impacts.
- Dredging should not be viewed as a viable method for managing aquatic weed and algae growth. Only about 10% of the ponds that have been dredged in New England for the purpose of managing plant growth have effective management for more than two years. Most ponds experience a regrowth of aquatic vegetation quite readily after dredging.
- If not dredged to sufficient depths, deepening of near shore areas is inconsistent with some recreation uses, especially swimming.

Long-Term Effects

Deepening of a pond/lake and removal of all organic matter may be desirable. However, in certain cases, dredging can fail to solve weed and algae problems.

Harvesting

Specially designed machinery has been developed by various manufacturers to cut, capture, and remove aquatic plants from ponds/lakes.

Cost

Weed harvesting costs from $350 to $1,000 per acre. A reasonably sized aquatic harvester costs between $60,000 and $80,000. Experience indicates that the machines will need to be replaced or totally reconditioned every five to seven years. Annual maintenance and operation of the harvester may cost from $6,000 to $10,000.

Benefits

- Removal of plants and nutrients from pond/lake.
- One to two acres of weeds can be harvested each day.
- The method is site specific, i.e., this method affects only those areas that are harvested.
- Multiple use of the water body may continue during harvesting.
- After composting, harvested vegetation may provide a beneficial mulch and fertilizer for local farmers and gardeners.

Detriments

- Harvesting is reactive. That is, managers must wait for the problem to occur before applying the solution, because harvesting is most effective after the weeds have grown to the surface and have already become a nuisance
- Harvesting is a relatively slow process (1 to 2 acres per day); thus, people using the lake near infested areas will have to tolerate nuisance conditions for long periods of time while waiting for the harvester to make its rounds.
- Plants need to be harvested at least once, and in most cases twice a year.
- Harvesting kills many fish, frogs, turtles and other aquatic fauna that get caught in the weeds.
- Harvesting fragments aquatic plants. These fragments may re-vegetate in other areas of the pond/lake, spreading weeds to new areas of the lake.
- Plants may grow faster and healthier after harvesting.
- Harvesting can not be conducted in or around shallow areas, docks, boulders, or stumps.
- Harvesting can not selectively manage specific plant species.

- The equipment may emit some petroleum products during operation.

- In shallow areas, major disruption of sediments can occur with the release of nutrients.

- The plant's reproductive activities continue relatively unimpeded.

Long-Term Effects

Harvesting and removal of vegetation does remove small concentrations of nutrients. However, aquatic weeds are not rich in nutrients, so harvesting does not usually result in significantly reduced nutrient levels. In other words, regrowth of all aquatic plants after harvesting is quite common.

Hydroraking

This type of machine is operated with the use of a diesel engine and hydraulic system. Basically it consists of a backhoe mounted on pontoons or a barge, with a large rake attached to the backhoe arm.

Cost

Cost ranges from $1,000 to $2,500 per acre.

Benefits

- Removal of plants from lakes and ponds.

- Removal of associated nutrients from lakes and ponds.

- Removal of some root systems and some sediment.

- The method is site specific. Only those areas hydro- raked are significantly disturbed.

Detriments

- Fragments aquatic plants which may re-vegetate other areas of the pond/lake.

- Reduces reproduction of aquatic fauna dependent on weed beds.

- Disturbance and suspension of sediments which may significantly increase turbidity and nutrient levels.

- Aquatic plant raking can not be done around rocks, boulders, stumps, docks or moorings.

- The reproductive activities of the plants which are not raked continue relatively unimpeded.

Long-Term Effects

Normally aquatic plant raking has a one to three year period of effectiveness.

Aeration

Aeration can be an effective method of managing the water chemistry to benefit certain aquatic species and to prevent release of manganese, iron and phosphorus from the sediment. It is not effective on macrophytes, but can be used to help manage microscopic algae growth in deep lakes.

Cost

The cost usually ranges from $2,000 to $5,000 per acre.

Benefits

- Increased oxygen level in the water column can benefit fish life.

- Aeration can assist in stabilizing and/or manipulating the food chain to help preclude nuisance growths of microscopic algae.

- If the flow around the aeration device is sufficient, it can help preclude the reproduction of Duckweed and Filamentous Algae.

Detriments

- Aeration should not be considered as a management tool for aquatic macrophytes.

- Aeration devices need to be installed properly so that they will not stir up sediments.

- Aeration devices need to be maintained and in most instances installed and removed annually.

- Improperly sized may increased algal biomass.

Long-Term Effects

As long as the aeration equipment works properly, some benefits can be realized from water quality improvement.

Hypolimnetic Aeration

Aerating of the hypolimnium in a stratified body of water can assist in reducing the nutrient release of sediments. This method is accomplished with the use of electricity, air compressors, and specially designed equipment.

Cost

The cost varies greatly depending on the size of the lake, basic cost for aeration equipment and pump house. Approximately $2,000 to $25,000.

Benefits

- Increase in the oxygen content of the hypolimnium.

- Reduces the ability of nutrients to be released into this area of the water column.

- Reduction of the nutrient release from the sediments to help preclude mixing these nutrients into the epilimnium.

- Improved cold-water fishing.

Detriments

- This method will not reduce macrophyte growth in the lake.

- High initial cost.

- Continued maintenance and operation costs.

Long-Term Effects

In certain specific applications this method can be viewed as a good, long-term management technique as long as it continues to be implemented. The increased oxygen level in the hypolimnia will prevent leaching of nutrients from the sediment as long as it is maintained.

Hypolimnetic Withdrawal

The method of withdrawing the hypolimnetic water can be used to reduce the nutrient loading to the lake by removing those waters which are high in nutrients. By replacing low oxygen bottom water with high oxygen surface water, will improve the oxygen levels at the bottom.

Cost

The initial cost to install the hypolimnetic withdrawal system can vary between $3,000 and $100,000 depending on needed modification to dam outlet structure. Maintenance of the system is low after installation.

Benefits

- Removal of nutrient-rich waters in the bottom of the lake.
- Reduction of overall nutrient budget to the lake from the release of phosphorus from sediments.
- Improvement of hypolimnetic oxygen.

Detriments

- High initial construction costs.
- Limited to lakes with adequate flushing during summer.
- No application to macrophyte problems.

Long-Term Effects

This method can be viewed as a very beneficial long-term method of nutrient management.

Sediment Oxidation

Oxidizing the nutrient-rich sediments can provide management of the release of these nutrients to the water column. There have been various methods for accomplishing sediment oxidation including water level drawdown, rototilling the sediments, and the use of special equipment to inject oxygen into the sediments.

Cost

The cost range for this method ranges from $1,000 to $5,000 per acre.

Benefits

- By oxidizing the sediments the nutrients are chemically bound to other sediment particles and thus are not available to be released into the water column.
- With the reduction of nutrient release into the lake from sediments, a lower nutrient budget may be realized.

Detriments

- Initial disruption of the sediments during the physical process of aerating sediments.
- Substantial nutrients and other chemicals may be released into the water column.
- This activity disrupts and disturbs living organisms dependent on the sediment surface such as freshwater mussels, crayfish, and benthics.
- Can cause temporary or permanent turbidity of water column.
- Somewhat experimental. Not well tested.

Long-Term Effects

Eventual stabilization of the sediments with this method may help reduce the overall nutrient loading to the lake.

Dilution and Flushing

In certain instances the use of a source of water lower in nutrients can be used to dilute or replace the water in a pond or lake.

Cost

Site specific costs are based upon availability of water supply source.

Benefits

- This method can flush out and reduce nutrient concentrations of lake water.

Detriments

- There are very few bodies of water where this method can be implemented due to the availability of sufficient volumes of clean water.

- If groundwater is used it must be from out of the watershed or bedrock wells.

- Colder unoxidized water from ground can cause serious water quality problems when released into the pond.

Long-Term Effects

Can be used as a very beneficial long-term solution for water quality problems.

Artificial Circulation

This method can be used to scour the sediments therefore precluding the ability of weeds to establish themselves. The equipment needed for this method involves underwater electric motors with propellers, and/or outboard motor boats fastened to stationary objects. The objective is to physically scour and move the sediments.

Cost

Cost ranges from $5 to $20,000 per acre.

Benefits

- In small limited areas, this method can be used to physically wash away the macrophytes. This method will only work effectively in the area where sufficient flow disrupts the macrophytes and sediments.

- By the continued circulation of the water over the sediments the re-establishment of macrophytes can be precluded.

Detriments

- The plants and other particulate matter which are flushed from the specific management area can cause problems elsewhere. In other words, floating vegetation and resuspended sediments can be deposited on nearby beaches or other property owners shorelines.

- Fragmentation of plants can encourage them to spread and propagate.

- Reproduction and feeding activities for aquatic organisms are completely disrupted.

- The initial cost of this method is high and requires continued maintenance costs.

- This method can only be used in small areas around docks, moorings, and/or marinas. Due to the limited area and depth involved, this method will not cause mixing of stratified lakes and/or the warming of the hypolimnia under normal circumstances.

Biological Techniques

Grass Carp

Grass carp are an exotic herbivorous fish native to China. These fish are widely used in aquaculture and as bio-control agents for aquatic plants in certain states in the United States. They eat a wide variety of aquatic plants but prefer certain types of plants.

Cost

To prevent the accidental escape and survival of this non-native species, only sterile fish are permitted by many states. Costs for sterile fish are higher, since the population cannot grow naturally. Massachusetts prohibits stocking of grass carp. A number adequate for control must be stocked and maintained in the face of natural mortality.

Benefits

- This fish will effectively eat almost any aquatic plant.
- These fish are long-lived--5 to 20 years--so control can also be long-lived.
- Cost per acre, over a number of years, is relatively inexpensive.

Detriments

- Grass carp will first eat the plants that they prefer. They may eliminate or severely reduce beneficial native plants before affecting nuisance species.
- State agencies must first approve stocking of exotic fish, and Massachusetts has not allowed the stocking of this fish for any reason or under any circumstances.
- If too few are stocked, control is ineffective. If too many are stocked, the fish can completely eliminate weed beds which are an important part of the aquatic ecosystem.
- The carp may disrupt reproduction activities and survival of native fish and fauna.
- Increased turbidity because of rooting.

Long-Term Effects

Aquatic vegetation can be effectively eradicated by these fish for a number of years. Total eradication of weedbeds, however, can negatively affect native fish that rely on some vegetation.

Pathogens

Researchers at the University of Massachusetts are currently working on a fungus to manage Eurasian Milfoil, a very serious pest species. While early results are promising, this cannot be considered a viable option at the present time due to many unanswered questions.

Insect Pests

Insect pests have been successful in controlling some aquatic weeds in the Southern U.S., but no insect pests are currently available to control aquatic weeds that grow in the northeast. Some current work focuses on the use of a moth caterpillar on milfoil. This work is in initial stages, and data on the moth's effects are just too scanty to estimate its probable effect on milfoil, much less to guide a successful application.

Biological control of aquatic plants remains a desirable but elusive goal. No bio-control techniques are ready for immediate application in Massachusetts.

Food-Chain Manipulation

The nutrients contained within a water body are divided among different links in the trophic level. Depending on the structure of the biological community, the nutrients can be contained in either inorganic nutrients, phytoplankton, zooplankton, small fish, or large fish-eating fish. Perceivable water quality problems occur only when the nutrients and biomass predominate in the second trophic link - phytoplankton. Manipulations that cause other links in the trophic chain to predominate will reduce the amount of biomass contained within the phytoplankton and, thus, improve water quality.

Because the next highest level consumes the trophic level below (that is, small fish eat zooplankton, zooplankton eat phytoplankton, and phytoplankton consume nutrients), alternate levels of the trophic chain tend to predominate within a lake/pond. Therefore, lakes/ponds are dominated by small fish and phytoplankton, or they are dominated by large fish, zooplankton, and inorganic nutrients. The lake/pond can be shifted to the latter situation by stocking large fish. This technique is called trophic chain manipulation, or bio-manipulation.

Cost

The cost is very inexpensive. Only the cost of stocking and protecting large fish-eating fish.

Benefits

- Can be viewed as a more natural method.
- Inexpensive.

Detriments

- Somewhat experimental.
- Incompatible with angling.
- May work successfully only in lakes with low nutrient concentrations.
- Does not affect macrophyte growth.

Long-term Effects

No long-term effects.

Chemical Techniques

Herbicides and Algicides

Aquatic herbicides and algicides have been used successfully for several decades. Millions of acres of ponds/lakes are treated annually in the United States, and several thousand acres of nuisance aquatic vegetation are managed here in the Northeast. Herbicides generally inhibit specific plant processes or degrade specific plant structures, such as interfering with photosynthesis or disrupting the cell wall of plants. This specificity allows herbicides to have very high effectiveness while being non-toxic or minimally toxic to animals and humans.

Costs

Cost ranges from $300 to $800 per acre.

Benefits

- Used properly, herbicides will not adversely affect fisheries or other aquatic fauna.
- In certain cases, specific plant species can be managed while not affecting other more desirable aquatic plants.
- The technique is somewhat site specific. With proper application, only target areas will be affected.
- Many herbicides kill both above ground (sediment) and below ground portions of the plant. Thus, this method can be a medium-term solution (i.e., several years per application).
- The technique is pro-active. One can apply the herbicides before the plants grow to nuisance heights and/or densities.
- The application and effect of herbicides are fairly quick. Residents need not tolerate long periods between effective management.
- By properly treating the pond/lake's aquatic plants, the natural reproduction of those plants is precluded.

Detriments

- Caution must be used by the applicator.
- When used in high concentrations these compounds can be toxic to the user and other living organisms.
- There may be restrictions to the pond/lake's water usage for a short period of time.
- Potential impacts on adjacent drinking water wells and/or downstream surface water reservoirs may occur if herbicides are not used properly.
- Herbicide application may secondarily cause fish kills, because decay of dense weeds may deplete dissolved oxygen. This does not, however, normally occur in ponds/lakes in the Northeastern U.S., and the chances of fish kills due to oxygen depletion can be further minimized by proper herbicide application.

- Some herbicides leave residues that remain in the sediments for several months or in some cases years, although most currently registered herbicides break down relatively quickly.
- Many people fear the use of chemicals and feel uncomfortable with their use.

Long-Term Effects

Plants are eliminated rather than clipped, so control can be relatively long-term (greater than one year). As opposed to many other techniques, herbicides kill the plant and its process for reproduction. Thus, this technique can significantly retard dispersion of nuisance macrophytes before they become well established in a lake.

Although research on the short and long-term effects of herbicides and algicides continues, most of the herbicides which are approved for use have repeatedly shown that there are no detrimental long-term effects (in the research that has been conducted over the past twenty to forty years). Several herbicides are currently undergoing U.S. Environmental Protection Agency re-registration procedures. This process requires that substantially new data be developed regarding short and long-term effects.

Alum

Application of aluminum compounds to bind phosphorus. This compound is not considered a herbicide or algicide by Federal and state regulating authorities. It has been used very successfully in treating both drinking and waste waters to manage various pollutants. Recently alum has been used successfully in managing lakes and ponds for both algae growth and precluding the release of nutrients from the sediments.

1. Alum Used for Total Water Column Treatment

Cost

The cost range is from $50 to $250 per acre.

Benefits

- Requires very few, if any, permits.
- Is non-toxic to aquatic organisms (providing pH of the water is maintained at an acceptable range for aquatic organisms).
- Benefits from treatments are realized within one to two hours after the treatment. These benefits can be documented through sample analysis, but more readily observed visually by the human eye. The benefits include: mortality of microscopic algae, flocculation of suspended materials, and generally the significant improvement in the water's temperature.
- Alum flocculates nutrients and other particulate matter out of the water column.
- Water clarity is greatly improved.
- Algal blooms can be precluded if sufficient nutrients are removed from the water column.
- A treatment can be an effective management tool for the entire season or in deep lakes, even longer.

Detriments

- If the water body is diluted after the treatment, the treatment can become ineffective.
- If the pH drops sufficiently during and after the treatment, aquatic fish and other organisms can be adversely affected.
- The treatment has no impact on macrophyte growth.

Long-Term Effects

Depending on the rate of nutrient loading, alum can be either a short-term or moderate-term (five years or more) solution.

2. Alum Used to Seal Sediments

Alum can also be used in high concentrations and applied to the surface of the sediments for the purpose of precluding the release of nutrients from the sediments.

Cost

Cost range is from $200 to $1,000 per acre.

Benefits

- Alum can chemically tie up the nutrients for many years.
- It does not adversely affect the aquatic fisheries or other organisms living in the lake.
- It does not physically disrupt or destroy the organisms associated with the sediment surface.
- Can be viewed as a long-term management technique for overall nutrient budget.

Detriments

- Drops in pH of water in the area of the treatment can be fatal to some aquatic organisms. (The use of a second chemical to adjust the pH such as sodium aluminate or lime can preclude this problem.)
- Will not reduce macrophytes.

Long-Term Effects

This can be viewed as a beneficial long-term management tool for a lake's nutrient budget. Longevity ranges from two to ten years for sediment sealing.

Dye

Dyes are added to shade aquatic plants. The most popular product in this category is Aquashade. This product is primarily used to inpart an aesthetically pleasing color to the pond's water. In many states it is a regulated herbicide/algicide. Manufacturers claim it can be used to manage aquatic weeds and algae.

Cost

The cost range is from $200 to $500 per acre.

Benefits

- Can improve the aesthetic appearance of some ponds.
- By cutting down on certain light wave lengths, this method can reduce algal growth.
- If high concentrations are used, light penetration can assist in managing macrophytes.

Detriments

- If the pond has an outlet, many states require permits and licenses before application.
- Material is initially quite expensive and retreatments will be needed several times per year.
- These compounds due not have any toxicological affects on plant growth.

Long-Term Effects

This method cannot be viewed as providing any long-term benefits.

WATERSHED MANAGEMENT TECHNIQUES

Historically, communities throughout Massachusetts have relied upon local bylaws and regulations to protect water resources from both point source (direct discharge such as sewage outfall pipes) and non-point source (stormwater discharge from catch basins or septic systems) contamination. Although these regulatory tools are typically adopted and implemented on the community level, many of these tools are directly applicable to the DEM. Some may also be adopted as park regulations (such as phosphorus detergent bands).

In cases where the DEM only controls land activities in a portion of a lake's watershed, the greatest means of watershed protection may be at the community level. In this case, DEM staff may assist local communities in adopting these controls. Many of the subdivision regulations, health regulations and wetland regulations affect activities at the site level (i.e. waterways buffers, underground fuel tanks, septic system placement etc.). These controls are intended to minimize water degradation resulting from improper site design. These site design controls are as applicable to the DEM as to private land developers, and should be followed when designing and managing parks. Figure 4.1 presents the lake and pond watershed management techniques discussed in this section. The following is a discussion of the various tools available to communities for lake protection.

Regulatory

Zoning

1. Overlay Ground and Surface Water Protection Districts
2. Prohibition of Various Land Uses
3. Special Permitting
4. Large Lot Zoning
5. Site Plan Review
6. Waterway Buffers
7. Performance Standards
8. Transfer of Development Rights
9. Cluster Design

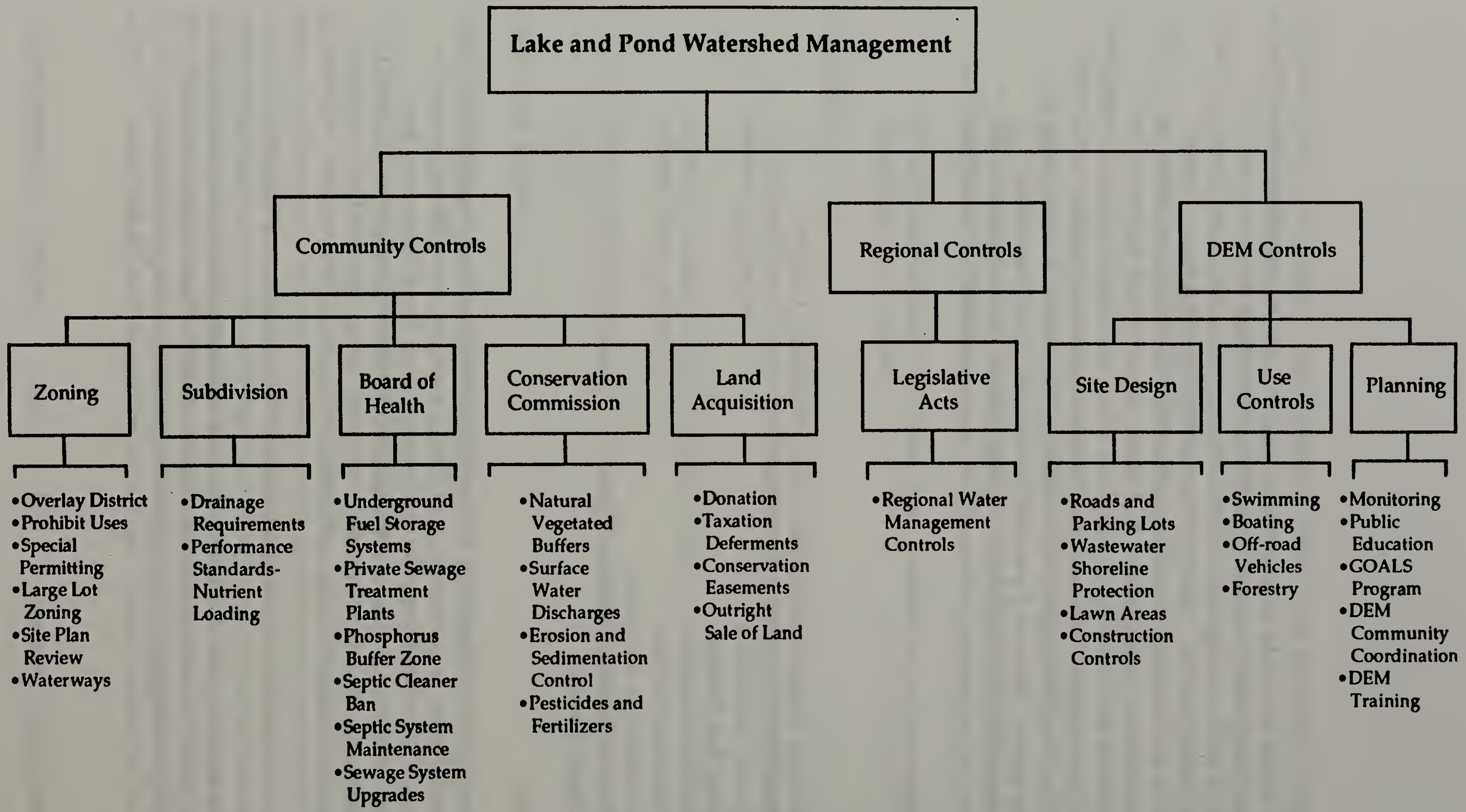
Discussion

Zoning regulation, as provided for in state enabling statutes, has been used to segregate different and, possibly, conflicting activities into different areas of a community. Most of Massachusetts' communities have recognized the limitations of this segregation approach as it relates to resource protection; particularly as state statutes provide extremely broad "grandfather" protection to a myriad of uses, structures, and lands.

1. Overlay Ground Water and Surface Water Protection Districts

It is estimated that over 75 cities and towns in Massachusetts have adopted an overlay ground or surface water protection district. These ordinances and bylaws, while varying in their approach toward resource protection (i.e. prohibition of various uses vs. special permitting and/or performance

FIGURE 4.1 Watershed Management Techniques



criteria), are similar in their goals of defining the resource by mapping watershed or zone of contribution boundaries and enacting specific legislation for land uses and development within these boundaries (see Figure 4.2).

2. Prohibition of Various Uses

Virtually every city and town in Massachusetts prohibits various land uses from certain sections of the community; although the rationale behind such prohibition may or may not be related to water quality or land use protection. While not the most creative nor effective approach toward resource protection, prohibition of land uses such as gas stations, sewage treatment plants, landfills, or others involving the use, storage and disposal of toxic and/or hazardous materials is a first step toward the development of a comprehensive resource protection strategy.

3. Special Permitting

All enabling statutes in Massachusetts provide for the allowances of certain uses and structures upon the issuance of a special permit or a special exception. In Massachusetts, this authority is given in Section 9 of MGL Chapter 40A, the Zoning Act. The special permit, contrary to public opinion, is to be issued only for "uses which are in harmony with the general purpose and intent of the. . . ordinance or bylaw".

If applied strictly, the special permitting process can be used effectively to regulate uses and structures that may potentially degradate water and land quality. For example, many communities use the special permitting process to prohibit underground storage tanks or limit lawn fertilizers within designated surface or ground water protection districts. Of critical importance, however, is the development of strict procedural and substantive guidelines for the issuance of special permits.

While most communities have established some guidelines for the issuance of special permits, few have developed broad, inclusive language to ensure that the special permit granting authorities have the powers to protect natural resources from uses or structures developed via a special permit.

4. Large Lot Zoning

Large lot zoning, as the title implies, seeks to limit water resource degradation by reducing the number of buildings and, therefore, septic systems from within a critical resource area. Large lot zoning has very limited effectiveness in rapidly growing areas, as zoning and subdivision enabling legislation

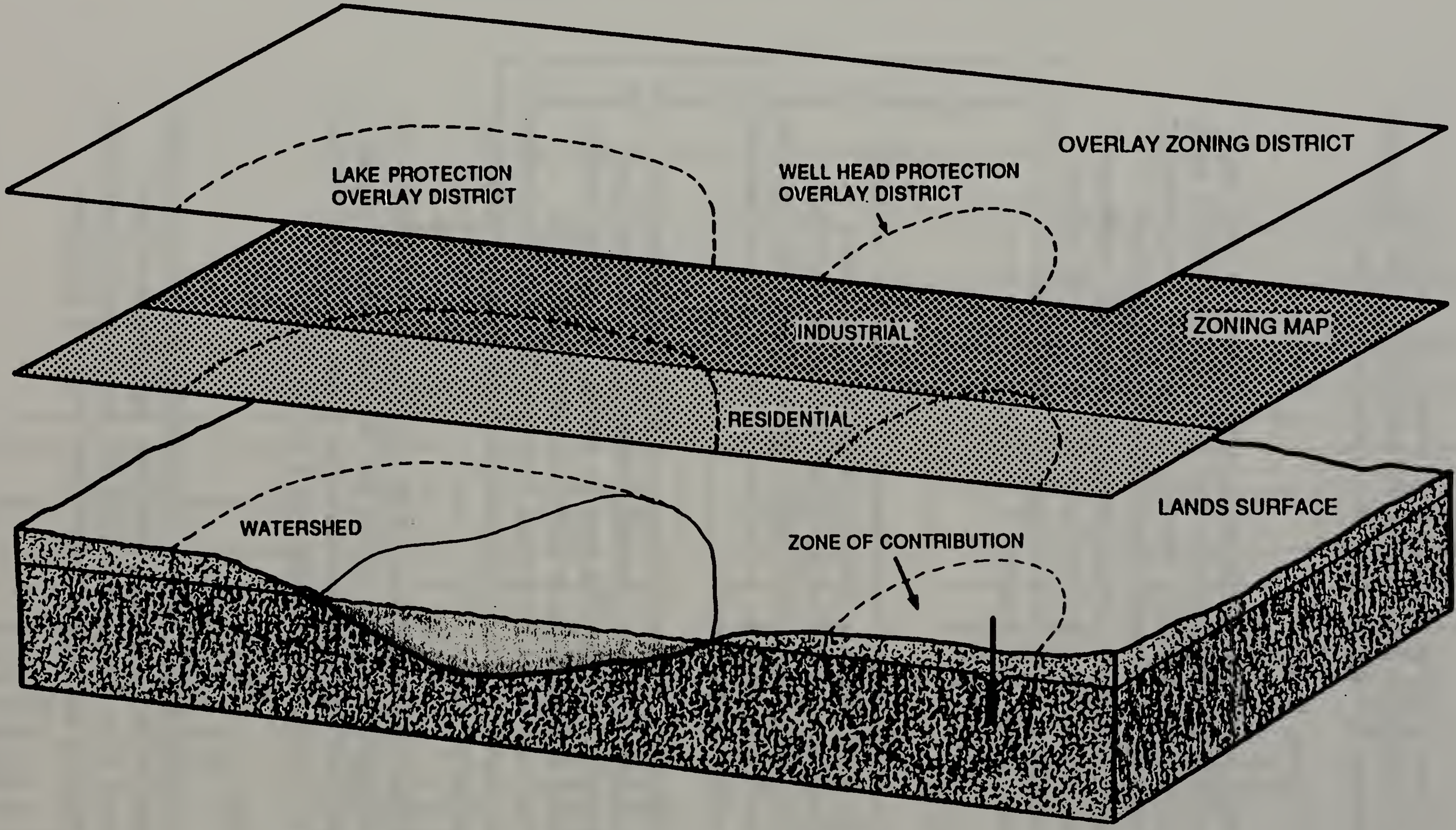


FIGURE 4.2
Water Resources Overlay Zoning Districts

HWH, Inc.

provide broad protection to land owners from increases in minimum lot sizes. Nevertheless, when used as part of an overall resource protection strategy, large lot zoning within appropriate areas (watersheds or zones of contribution to public supply wells or reservoirs) can be an effective tool against water contamination and pollution. Large lot zoning provides a simplified means of reducing impervious surface areas, and therefore reduces stormwater run-off in an area. Dependent upon environmental conditions, this may aid in preventing surface water pollution. However, large lot zoning may encourage sprawl if it is not coupled with flexible site standards to allow the clustering of structures. Therefore, when used as a part of an overall resource protection strategy, flexible large lot zoning may be a useful tool in maintaining water quality.

5. Site Plan Review

Site plan review is an administrative procedure which can be used to ensure compliance with design standards for drainage, building size and location, landscaping, and impervious surfaces to ensure that proposed developments meet protection standards. In Massachusetts a municipality can require that every project in a zoning district submit to site plan review. More typically, communities require site plan review for commercial and industrial uses, and larger residential subdivisions and multifamily developments. The primary advantage of using this tool is that it ensures compliance with the zoning bylaw; however, the need for detailed review of these projects may overburden staff resources. Therefore, site plan review is usually restricted to key areas. Site plan review may be appropriate for all land within the surface watershed and ground water contributing area to a lake.

6. Waterways Buffers

Vegetated buffer strips are of tremendous value in protecting wetlands and surface waters from a variety of impacts. Buffer strips serve to contain and allow infiltration of surface run-off, thereby preventing pollution through the attenuation of nutrients, heavy metals, hydrocarbons and other contaminants. In addition, buffer strips provide critical habitat and travel corridors for a variety of species. Buffer strip requirements can be incorporated into local zoning, subdivision and wetland bylaws.

7. Performance Standards

Performance standards are based on the assumption that any given resource has a threshold, beyond which the resource's ability to function deteriorates to an unacceptable level. Performance controls assume that most uses are allowed in a designated area provided that the use or uses do not, and will not, overload either natural or man-made resources.

The advantage of using performance standards is that it focuses additional regulations on specific impacts without burdening all uses in a zoning district, and it regulates land development impacts without prohibiting development. A good example of performance standards designed to protect water supplies from excessive contaminants is the establishment of "critical" threshold limits as the bottom line of acceptability. A limitation to the use of this tool is that changes in environmental standards and sensitivity to emissions will require amendments to bylaws. Review standards must be clear and objective.

Performance standards are used throughout Massachusetts. In aquatic systems, excessive nutrient levels may cause excessive plant growth and other signs of pollution. Phosphorus is generally considered to be the limiting nutrient for growth in freshwater surface supplies, while nitrogen tends to be the limiting nutrient for marine systems. To lessen excessive plant growth in estuarine systems, many towns on Cape Cod currently base the intensity of allowable development in their water resource recharge areas upon the level of nitrogen loading generated by a proposed development. Towns throughout Massachusetts could adopt similar standards to control nutrient loading to lakes and ponds.

8. Transfer of Development Rights

The idea of "transfer of development rights" (TDR) is based on the concept that a parcel of land has a bundle of different "rights" associated with it. The value of these rights, such as the right of possession, access, air rights, subsurface rights, and development type and density, are defined, in part, by governmental actions such as zoning. A TDR program allows a landowner to separate his or her right to develop the land, as permitted by zoning, from the other rights associated with the land, and sell those development rights.

To implement a TDR program, a governmental entity such as the town would prepare a plan designating the parcels or districts from which development rights could be transferred (a "sending" or "donor" parcel), and the parcels or districts which would receive those development rights and develop at a higher density than allowed by the underlying zoning district (a "receiving parcel"). Typically, a sending parcel or district might be perceived by the town to have importance either as recharge to a public water supply or within close proximity to a surface water body or public supply well. A receiving parcel is able, both from a physical standpoint and in terms of the community's growth program, to accommodate additional development beyond that allowed as-of-right by zoning. In selling his or her development rights, a landowner would gain the cash value of whatever development rights the market associates with the land, and yet would keep the land in a less intensive use and, presumably, continue to enjoy lower property taxes. A perpetual easement or some other development restriction would be recorded with the deed of the sending or donor parcel. The purchaser of the development rights gains the ability to develop the receiving parcel at a higher density than allowed "as-of-right" and can recapture the cost of the development rights purchased through the more intensive use of the receiving parcel.

Use of TDR in Massachusetts is limited. At least four different communities have adopted, or are in the process of adopting TDR bylaws: Sunderland, in western Massachusetts; Townsend, in central Massachusetts; and Mashpee and Falmouth, on Cape Cod. Although similar in many respects, each was designed with different resource protection issues as a goal. Sunderland's program is for agricultural protection, Townsend's for scenic view and vista protection, Mashpee's for general resource protection and Falmouth's for water resource protection. Use of TDR provisions have been used, or are under serious consideration, within these communities. However, Sunderland's bylaw is not yet fully developed, and Townsend's and Mashpee's bylaws have only recently been adopted and have not yet been used. Falmouth's TDR bylaw has been infrequently used.

The best examples of areas where TDR bylaws have been adopted and are being implemented are Montgomery County, Maryland and the Pinelands, New Jersey. Numerous reviews and critiques of these programs can be found in the planning literature. Towns interested in adopting TDR bylaws should review these two programs to gain better knowledge of how their own TDR program should be designed and implemented.

9. Cluster Design

Cluster zoning is an alternative to the standard grid-style subdivision. In a cluster development, smaller building lots are allowed, with resulting land savings set aside in contiguous areas of open space. These open spaces may be designed to provide wildlife habitat and to maintain existing wildlife corridors. Clustering can be done at the same density as could be obtained in a grid system, or with greater density "bonuses". Typically, cluster development allows shorter streets, reducing construction and maintenance costs. It provides tremendous flexibility for both the developer and municipality, and often allows for greater creativity in the division of large land parcels.

Subdivision Control Rules and Regulations

1. Drainage Requirements
2. Performance Standards/Nitrogen Loading

Discussion

Subdivision regulations as provided for in state enabling statutes "fine-tune" zoning bylaws and ordinances in that they focus less on land use and more on engineering concerns such as street construction (grade, width, intersection angles), utility placement and traffic patterns of individual subdivisions. Protecting water resources via subdivision control, therefore, is far less effective than through zoning, particularly as it is the expressed intent of the subdivision legislation that plans which meet a community's subdivision rules and regulations are to be approved by the Planning Board.

1. Drainage Requirements

Drainage from roads and lawns within subdivisions contribute significant contaminants to water supplies. However, as part of the subdivision review process, Planning Boards have an excellent opportunity to protect water supplies through the use of strong drainage requirements.

Standards for catch basin maintenance and stormwater infiltration, specificity on the type of catch basins and infiltration devices to be used, and limitations on lawn fertilizer applications within designated resource areas are three examples of drainage standards Planning Boards can employ when reviewing subdivisions. Many communities have developed strong drainage requirements through their subdivision rules and regulations, and some have developed standards that are geared directly toward water resource protection.

2. Performance Standards

As noted above, Planning Boards have significant opportunities to ensure that new subdivisions do not contribute to water resource contamination during the subdivision review and approval process. One means in which to ensure that water quality will be maintained is to regulate subdivisions based upon the degree to which the subdivision will impact water quality assuming the subdivision is fully developed. For example, it is possible to determine the water quality impact of a 20-lot subdivision, calculating the nitrogen and/or phosphorus contribution from roads, lawns and septic systems. It is also possible to determine the "carrying capacity" or ability to absorb nitrogen and phosphorus loading of a receiving water system. Planning Boards can use this information to regulate subdivisions within critical resource areas by limiting subdivision development to the point that water quality will not be compromised.

Health Regulations

1. Underground Fuel Storage Systems.
2. Privately-Owned Wastewater Treatment Plants (Small Sewage Treatment Plants).
3. Phosphorus Buffer Zone.
4. Septic Cleaner Ban.
5. Septic System Maintenance.
6. Sewage System Upgrades

Discussion

The development of health regulations as provided for in Massachusetts' enabling statutes, is an extremely effective method of rounding out a communities regulatory protection program.

1. Underground Fuel Storage

Leaking underground fuel storage systems may be the single largest source of ground water contamination in the nation. A recent study by the Environmental Protection Agency estimates that 35% of the tanks in the ground today are leaking. Specifically, the larger underground gasoline storage tanks associated with automotive service stations have caused numerous ground water contamination incidents. In response to the problem, most states have adopted regulations which govern the larger tanks associated with service stations. The regulations control the construction of new tanks and require leak testing and ultimate removal of existing tanks.

However, an indepth review of this legislation reveals that three additional protections should be adopted to enhance local-level ground water protection. These are: 1) prohibit new residential underground fuel storage tanks townwide as they cannot be adequately monitored; 2) remove existing residential underground fuel storage tanks; and 3) prohibit all new underground tank installation (except for replacements) within ground or surface water resource areas.

2. Small Sewage Treatment Plants

Small sewage treatment plants (SSTP's) formerly referred to as "package treatment plants" have been utilized as a technological solution to overcome the natural capabilities of land and associated water resources to assimilate the disposal of wastewater. This technology has enabled the development of projects which exceed the existing carrying capacity of the land using proven conventional wastewater disposal technologies. The use of SSTP's have both pros and cons. SSTP's may have positive water quality benefits since they are able to treat sewage to a greater degree that is possible through using conventional septic systems. However, the effectiveness of SSTP's is dependent upon the proper functioning of more technological components than that associated with a relatively simple conventional systems. They are also largely dependent upon a much greater level of supervised operation and maintenance. For these reasons, SSTP's are subject to a degree of uncertainty and malfunctioning. At this time there is little information about the track record of these systems. The systems are typically utilized in environmentally constrained sites. In these situations, a malfunction can result in serious environmental degradation (including drinking water contamination, lake eutrophication, fish kills, and shellfish contamination). To eliminate these risks in critical water resource protection areas, many communities have banned the use of SSTP's or prohibited their development within designated surface watersheds or zones of contribution to public supply wells. A Generic Environmental Impact Report is currently underway which will attempt to resolve many of these issues.

3. Viral Buffer Zone

Viruses are capable of moving distances of over 300 feet through ground water from wastewater disposal sources. They are inactivated through a biochemical decay process. Approximately 120 days is required to reduce viruses to safe concentrations. In permeable sand and gravel deposits ground water (and potentially viruses) can migrate distances of 120-300 feet. Boards of Health may adopt regulations to require adequate separation distances between septic system leaching areas, tributaries and lakes.

4. Septic Cleaner Ban

Trace levels of volatile organic compounds have been detected in many municipal wells throughout Massachusetts. These chemicals are likely to be the result of the cleaning of clogged septic systems with products containing synthetic organic chemicals. Alternatives include better maintenance of systems, sewage system upgrades and hydrogen peroxide treatment or physical cleaning for clogged systems. To minimize the risk of future contamination of ground water by septic cleaners, many communities (mostly on Cape Cod) have prohibited the storage, use or disposal of septic cleaners containing synthetic organic chemicals.

5. Septic System Maintenance

The maintenance of on-site septic systems is frequently overlooked. The result is typically an overloading of solids moving to the leaching facility and subsequent clogging. When this occurs, the system needs to be rehabilitated. This is commonly done with the use of strong acids or organic solvents. These chemicals are ground water contaminants and can degrade water quality in downgradient wells. To minimize this and to ensure proper maintenance of septic systems, many boards of health have developed a voluntary septic system maintenance program.

6. Sewage System Upgrades

Many existing septic systems (including cesspools) do not meet state minimum criteria. These systems are subject to a higher probability (and frequency) of failure. Failures may result in clogging (and subsequent cleaning with organic solvents), overflowing, and water contamination. To encourage more frequent upgrading of septic systems to state and local standards, numerous cities and towns that rely principally on septic systems for waste disposal have developed septic system inspection programs that are triggered upon a real estate transaction or the issuance of a building permit to expand, alter or change a pre-existing, nonconforming structure.

Wetland Bylaws

1. Natural Vegetated Buffers
2. Surface Water Discharges
3. Erosion and Sedimentation Control
4. Restrictions on Pesticides and Fertilizers

The Massachusetts Wetlands Protection Act, M.G.L. Chapter 131 Section 40, is administered by Conservation Commissions at the local level and by the Department of Environmental Protection at the state level. This Act and its associated regulations provide for the protection of most wetlands; however, in the case of an appeal of local determinations, the Commonwealth has jurisdiction. To augment the protection of wetlands afforded by the Wetlands Protection Act and to allow for an alternative in the case of an appeal, towns may adopt local wetland bylaws. In addition, towns may also choose to protect wetlands through the adoption of zoning bylaws, which designate wetland areas and their allowable uses. Local wetland bylaws adopted by Towns and subsequent regulations developed by local Conservation Commissions to support these bylaws are a valuable first line of defense in protecting coastal water quality.

It is a well-documented fact that wetlands are a critical component in the protection of both surface and ground water quality. Wetlands absorb and contain flood waters and have been shown to remove significant quantities of pollutants through a combination of physical, chemical and biological processes. Clearly, the first step in protecting water quality is to protect the wetlands themselves, both by enforcing the state regulations to their fullest extent and by adopting local bylaws to protect wetlands and wetland functions not fully protected by state law.

In addition to protecting wetland resources themselves, local conservation commissions also have jurisdiction over activities proposed within 100 feet of wetlands. Thus, the protection of water quality can be greatly enhanced by the judicious regulation of activities proposed within this buffer zone. Specific steps that commissions can take include: the requirement that a natural, vegetated buffer strip to be retained adjacent to wetland areas; stringent controls on surface water discharge to wetlands; restrictions on the use of fertilizers, pesticides and herbicides within close proximity to wetlands; and stringent erosion control requirements during construction activities. Recommendations for each of these are discussed in greater detail below.

1. Natural Vegetated Buffers

Natural vegetated buffers are tremendous value in protecting wetlands and surface waters from a variety of impacts. Buffer strips aid in reducing direct stormwater runoff discharge to surface waters, stabilize shoreline areas and provide wildlife habitat and corridors. Local Conservation Commissions may incorporate natural vegetated buffer strip requirements within 100 feet of wetland resource areas in their local bylaws and regulations.

2. Surface Water Discharges

Land development frequently results in increased discharges of surface run-off to wetlands and watercourses which may cause downstream flooding, severe alterations to wetlands hydrology, and degradation of water quality. Conservation Commissions are in a particularly effective position to regulate these impacts, due to their jurisdiction over all activities proposed within 100 feet of wetland resource areas. Commissions may prohibit the direct discharge of surface run-off from roads and other paved areas to wetlands and watercourses. Applicants may be encouraged to minimize the extent of paving within buffer zones and to use permeable paving materials where possible. Surface run-off should be recharged on site, using a combination of vegetated swales, detention basins and similar techniques.

3. Erosion and Sedimentation Control

The discharge of sediments to wetlands and waterways may have severe consequences, ranging from direct sedimentation of wetland flora and fauna to reduction in water clarity. Furthermore, many contaminants including phosphorus, heavy metals and hydrocarbons are readily adsorbed onto soil particles and are transported effectively through the process of siltation. To prevent direct siltation to wetlands and watercourses, Conservation Commissions may specify strict erosion and sedimentation controls for construction activities proposed within the buffer zone. Different types of erosion controls will clearly be required for different slopes, soil conditions and construction activities. Subsequent revegetation requirements may be specified in the Order of Conditions, to insure long-term site stability.

Two excellent publications are recommended as sources of specific erosion and sedimentation control techniques: Erosion and Sediment Control in Site Development (Volume I); and Vegetative Practices in Site Development (Volume II). These guides are published by the Soil Conservation Service, USDA and were developed for soil conditions specific to Massachusetts.

4. Restrictions on Pesticides and Fertilizers

Fertilized lawns may contribute substantial levels of nutrients, pesticides and herbicides to surface waters both directly, via surface water run-off, and indirectly via leaching to ground water. Recent literature suggests that the leaching of fertilizers from lawns to ground water may be less significant than initially proposed (i.e. only 10 to 30% leaches as opposed to 60 to 80%), however, in areas with steep slopes and poorly drained soils, surface run-off may be of concern. Therefore, it is recommended that Conservation Commissions restrict the extent, and particularly the location of lawn areas proposed within the buffer zones to wetland resources.

Non-Regulatory Techniques

As noted in the introduction, most Massachusetts towns have relied upon so-called "traditional" tools to protect water quality; zoning, subdivision and to some extent, health regulations. And, while these regulatory tools did serve a legitimate purpose, almost all New England cities and towns have recognized that over-reliance upon regulatory tools merely "programs" a municipality for development and allows little flexibility if the original program was inaccurate, or if better information has been made available since the program was devised.

Many communities in New England have taken advantage of non-regulatory options for resource protection, but perhaps the most comprehensive programs to date have been developed on Cape Cod, Massachusetts. All of the Cape's 15 towns have engaged in some form of non-regulatory land protection, ranging from bond issues to conservation easements to the establishment of land trusts whose sole purpose is the stewardship of land for, among other reasons, the protection of public and private water quality.

Although many non-regulatory water resource programs are available to cities and towns in New England, they have traditionally focused on four categories:

1. Donations
2. Taxation Deferments
3. Conservation Easements
4. Outright Sale of Land

1. Donations

Landowners are often in the position of being able to donate a piece of land (as part of a development project or an entire developable parcel) either to the community or a non-profit organization such as the Nature Conservancy. If so, they will find that giving the land for preservation costs them far less than they might think, particularly when a variety of tax savings are taken into account.

The initial benefit comes in the elimination of estate or capital gains taxes. In addition, real estate taxes, insurance and maintenance costs are avoided. And, the entire value of the donation can be deducted, over time, from federal income tax obligations.

2. Outright Sale of Land

Many communities are committed to the acquisition of selected parcels deemed so significant to the town's future that it may be willing to purchase them outright, at market prices. These acquisition priorities include, but are not limited to: large tracts of undeveloped land, land within defined water resource areas, land containing unique or rare and endangered wildlife and lands with unique ecological character. Outright sales of land can take four variations:

a) Sale at fair market value: The price a buyer is willing to pay a seller to purchase a piece of property.

b) Bargain sale: The sale of property below fair market value to a conservation organization or municipality. The difference between fair market value and the reduced price may qualify as a charitable deduction from income taxes.

c) Installment sale: The sale of property over a period of years. Installment sales allow the seller to spread the income from the sale over a several year period, thus deferring, and in some cases, reducing income taxes.

d) Sale with a reserved life estate: The transfer of property upon the death of the individual land owner. This option allows landowners to sell or donate now, but continue to use their property during their lifetime and/or the lifetimes of other members of their immediate family.

3. Tax Deferments

One factor that often pressures individuals into selling their land to development is the property tax, since it taxes land based on the market price for development, regardless of its present use. All New England states currently provide for some degree of real estate tax reduction for lands used, in general terms, for conservation.

4. Conservation Easements

An easement is a limited right to use or restrict land owned by someone else. Easements are either positive (rights-of-way) or negative (conservation, scenic) and may take a variety of forms. Positive easements can effectively assist a community in protecting land from development by restricting all or a portion of the property to open space or limited development uses. The granting of a conservation easement does not involve the transfer of ownership of the land; instead it means giving up certain development rights of the property. For example, a conservation restriction may restrict the number of houses to be built upon a parcel, restrict that parcel to only specified types of developments, or specify that portions of the parcel within sensitive watersheds or zones of contribution remain undeveloped in perpetuity.

Legislative Techniques

Legislative growth management strategies include those created by individual state legislative bodies. As local governments do not possess inherent sovereign power, their jurisdiction rests almost exclusively with state constitutional provisions, charters, statutes, ordinances and regulations. Legislative growth management strategies focus on approaches that states deem appropriate for state-wide or regional land management. For example, six communities sharing a common watershed for a reservoir may find that methods of protecting the watershed from contamination vary from community to community. Town 1 may have enacted stringent land use controls within the watershed. City 2, however, facing an economic decline, may be encouraging commercial growth in the watershed, particularly as the locus has easy access to the interstate highway.

Legislative growth management strategies provide an ideal mechanism to ensure that resource protection issues, as illustrated above, are addressed on a regional, as opposed to a piece-meal, basis. To avoid the obvious planning concerns of the example cited, the state could adopt a regional water management program requiring all communities sharing a common water resource to adopt stringent watershed protection measures. For example, all six communities within the common watershed could be required to adopt minimum lot size and use requirements commensurate with the goal of water quality protection. Moreover, the six communities--precisely because they are required to do so--can share the cost of defining the boundaries of the water resource and ideally assist each other in managing the area of concern. Similar legislative action to protect regional resources can be enacted for transportation corridors, wildlife and estuarine systems and uniquely scenic and historic landmarks. And while local governments may become concerned that their "home rule" authority is being usurped, history has proven clearly that critical natural resources cannot be adequately protected on the local government level alone.

During the 1989 Massachusetts Legislative session, Senator Carol Amick submitted a bill entitled "An Act to Provide for the Protection of Sensitive Water Supply Areas" (Senate, No. 1091) that would amend MGL Chapter 40A, the Zoning Enabling Act, to control the impact of development in sensitive water supply areas (Senator Barrett has since taken over responsibility for this bill due to the resignation of Senator Amick in 1989). Specifically, the bill would require that large-scale non-residential developments submit a detailed analysis of probable environmental impacts as a part of the special permit process for all land within: 1) 400 feet of a surface drinking water supply, 2) a zone II recharge area of any public water supply well, and 3) 500 feet from the point of withdrawal of any public water supply where its zone II recharge area has not been delineated. The bill would also prohibit the disposal of certain hazardous materials in these areas. While the bill's wording is not finalized and a final version is not expected to be resubmitted until the 1990 legislative session, the impact of such a bill, or revision to Chapter 40A, on growth management and reservoir management will be significant. The result would be that communities will be able to apply and enforce provisions of the revised Chapter 40A to ensure that proposed growth is managed in accordance with strict environmental standards.

A bill is currently before the Massachusetts legislature which would lessen phosphorus loading to groundwater, and subsequently, to lakes. Senate Bill 1599 was introduced by Senator Bill Keating, and would prohibit the sale of phosphate laundry detergents and cleaning agents throughout the Commonwealth. In areas where wastewater is serviced by septic systems, phosphates associated with these household items are released to groundwater. If this bill is adopted into law, more environmentally sound products would be available to consumers, and ultimately the level of phosphate loading would be reduced.

A bill is also currently proposed which would increase shoreline protection to rivers. Wherever possible, the proposed law would require a minimum setback of 100 feet along rivers. Although this act does not apply to lakes and ponds, similar legislation could be adopted.

Conclusion

The capability of land to support various uses differs widely from one parcel to another within Massachusetts. Some lands are well-suited to intensive residential or commercial development without creating environmental nuisances. Others, such as those defined as surface watersheds to sensitive lakes and ponds, have a limited capacity to support such development and their misuse can result in their loss of quality. The protection of environmentally sensitive lands within the municipality generally, and lands within the delineated water resource protection districts specifically, should be considered a high priority.

To that end, the above-noted regulatory, non-regulatory and legislative recommendations should prove useful in a variety of ways.

First, they supplement existing federal and state laws which, although designed to protect water resources, fall short of protecting water supplies from point and non-point contamination.

Second, their use will allow municipal officials to require data from developers in order to evaluate the impact of developments allowable under existing zoning, but which are clearly inappropriate when based upon the proposed development's impact upon existing water resources.

Finally, the adoption of these alternatives will represent a significant step toward public recognition that water systems are unavoidably linked to land development patterns and local land use practices. It also represents acceptance of the premise that water resources, up to now considered limitless in quantity, are a precious and finite resource.

Park Watershed Management Techniques

Site Design

Many typical park activities can serve as sources of nonpoint source pollution. For instance, park use may impact water quality through the direct discharge of runoff from roads and parking lots, through nutrient loading from wastewater and fertilizers generated in the park, and through sedimentation due to shoreline erosion, construction or forestry activities. The following is a discussion of how careful site design or alteration may be used to lessen the impacts of park use upon lake and pond water quality. Table 4.2 summarizes the impacts of each technique.

Roads and Parking Lots

Paved surfaces function as stormwater runoff sources because little or no precipitation can infiltrate through the pavement into the soil. Roads and parking lots also function as collection areas for a wide variety of pollutants: silts, oils and greases, VOCs, animal wastes, metals, suspended solids, nutrients, and salts (refer to Section II). This combination of functions means

TABLE 4.2 Watershed Management Impacts

Watershed Management Technique	Reduce Loading of Suspended Solids	Reduce Loading of Nutrients	Reduce Metals and Organic Materials	Improve Wildlife Habitat	Risk of Well Contamination
Stormwater Management:					
Grassed Swales	++	+	++	0	-
Infiltration Basin	++	++	++	0	--
Infiltration Trench	++	++	++	0	--
Porous Pavement	++	++	++	0	-
Detention Pond*	+++	+	++	+	+
Retention Pond*	+++	++	++	++	++
Constructed Wetland	+++	+++	+++	+++	+++
Wastewater Management:					
Septic System Siting and Maintenance	0	+	0	0	++
Wastewater Performance Standards	0	+++	0	0	+++
Small Sewage Treatment Plants	0	+++	0	0	-
Composting Toilets	0	+++	0	0	++
Solar Aquatics	0	+++	0	0	++
Shoreline Protection:	+++	+++	+++	+++	0
Lawn Area Best Management:	+++	++	+++	+	+
Construction Controls:	+++	0	+	0	0

Key:

+	low postive impact
++	moderate postive impact
+++	high postive impact
0	no impact or not applicable
-	low negative impact
–	moderate negative impact
---	high negative impact
*	positive impacts may be improved through addition of constructed wetlands

parking lots, driveways, roadways, and other paved surfaces may act as sources of significant quantities of these pollutants to nearby water bodies because their surface areas are often quite extensive.

Parking lots and roads may be an important source of pollution for lakes and ponds, particularly when stormwater runoff flows directly into the water body without any form of treatment. The following paragraphs describe a number of methods for treating or reducing surface runoff, most of which involve considerable construction costs. Wherever possible stormwaters should be allowed to percolate through the soil in areas at least 100 feet upgradient of water wells, lake shores or other sensitive receptors.

Effective initial design of parking lots and roads can help reduce the costs of runoff control by setting paved surfaces back from the water's edge and diverting stormwater runoff from these surfaces to runoff control structures. A variety of control structures may be used: detention ponds, wet ponds, infiltration trenches, infiltration basins, porous pavement, grassed swales and constructed wetlands. These control structures take advantage of one or more physical and/or biological mechanisms to reduce pollutant loadings: sedimentation, biological assimilation, filtration, and adsorption. They also vary in construction costs, operation and maintenance costs, ease of maintenance, land requirements, and efficiency in reducing different pollutants. Table 4.3 presents the level of cost and benefit for each technique.

TABLE 4.3
Comparative Costs of Stormwater Management Techniques

Technique	Construction Costs	Maintenance Cost	Water Quality Benefits
Grassed Swales	Low	Moderate	Moderate
Infiltration Basin	Moderate-High	High	Moderate-High
Infiltration Trench	Low-Moderate	Moderate-High	Moderate
Porous Pavement	High	High	Moderate
Detention Pond	Low-Moderate	Moderate-High	Moderate-High
Retention Pond	High	Moderate-High	High
Constructed Wetlands	High	Low	High

Detention and Retention Ponds

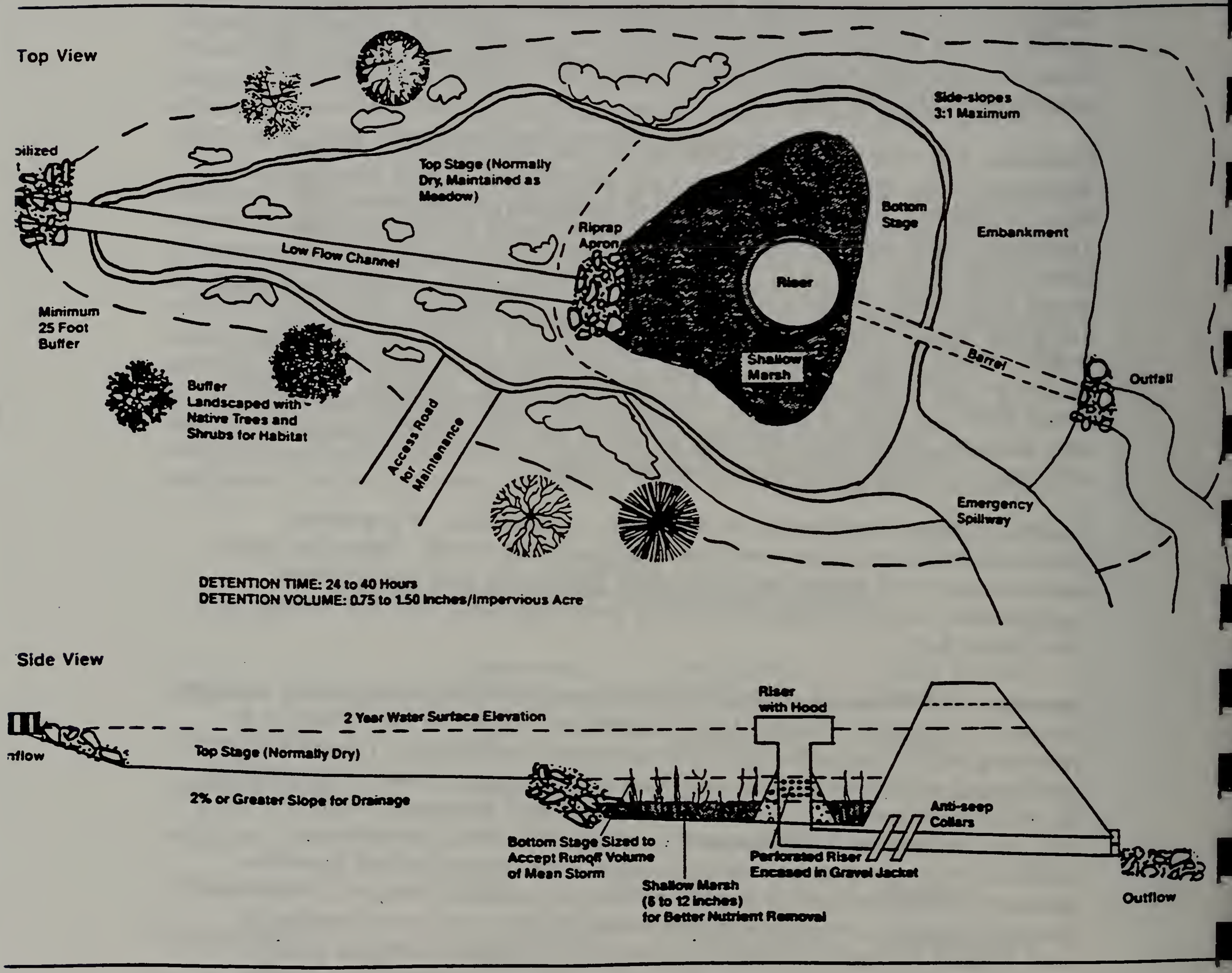
Detention and retention ponds are designed to hold runoff for extended period of time in order to reduce flooding, and to remove suspended solids (silts, etc.) and their associated pollutants (metals or organic compounds adsorbed to particulates).

Detention and retention ponds differ in the way that runoff is handled. Retention ponds are designed to capture and infiltrate runoff although some form of spillway is generally provided to handle large flood events. Detention ponds serve to detain and release runoff at a controlled rate. History has shown that if stormwater is detained for 24 hours or more, as much as 90% removal of pollutants is possible. Therefore, when using ponds for water quality benefits, extended runoff detention ponds or retention ponds should be provided. Ground water recharge is limited to the runoff which infiltrates through the pond bottom during the relatively infrequent times when the pond is flooded. While simple detention ponds are typically dry, extended detention ponds may be wet or dry. Figure 4.3 provides a schematic of a typical extended detention pond.

Another design consideration is to prevent resuspension of deposited materials by scouring basin sediments by incoming runoff. Retention ponds are generally "wet ponds" which retain a permanent pool and prevent resuspension of particulates by slowing incoming water with the existing pool (see Figure 4.4).

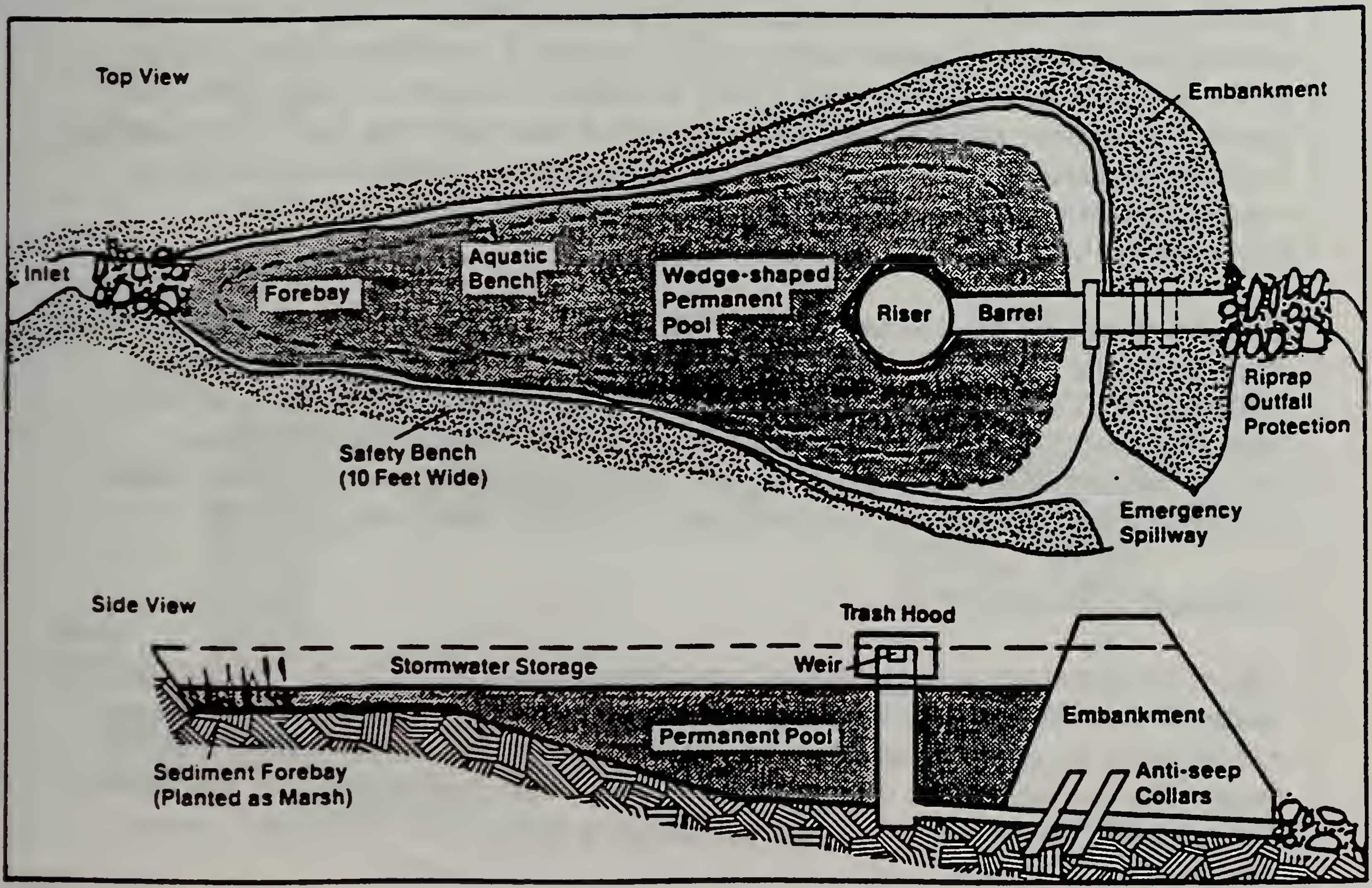
Retention and extended detention ponds are an effective water quality control measure. If properly designed and maintained, ponds are very effective in removing suspended solids and their associated compounds. Costs are site specific and vary considerably. In general, ponds cost between $15,000-$40,000. In cases where retention ponds are used, biological processes within the pond also remove soluble nutrients such as nitrate and ortho-phosphorus. Artificial wetlands may be created in association with extended detention ponds and retention ponds to provide further pollutant removal. Additional positive impacts of retention and detention ponds include the creation of local wildlife habitat and landscape amenities. Negative impacts include potential safety hazards, the need for regular maintenance and occasional nuisances such as algae, odor and debris.

FIGURE 4.3 Schematic of Extended Detention Pond Utilizing a Shallow Marsh


Top View
ilized
Top Stage (Normally Dry, Maintained as Meadow)
Side-slopes 3:1 Maximum
Low Flow Channel
Riprap Apron
Bottom Stage
Embankment
Riser
Shallow Marsh
Barrel
Outfall
Minimum 25 Foot Buffer
Buffer Landscaped with Native Trees and Shrubs for Habitat
Access Road for Maintenance
Emergency Spillway
DETENTION TIME: 24 to 40 Hours
DETENTION VOLUME: 0.75 to 1.50 Inches/Impervious Acre
Side View
2 Year Water Surface Elevation
Riser with Hood
nflow
Top Stage (Normally Dry)
2% or Greater Slope for Drainage
Anti-seep Collars
Bottom Stage Sized to Accept Runoff Volume of Mean Storm
Perforated Riser Encased in Gravel Jacket
Shallow Marsh (6 to 12 inches) for Better Nutrient Removal
Outflow

SOURCE: T.Schueler, 1987

FIGURE 4.4 Schematic of Wet Pond



SOURCE: T.Schueler, 1987

Infiltration Basin

A typical infiltration basin, shown in Figure 4.5, is an effective BMP for removing fine particulates and dissolved materials. Infiltration basins trap and hold runoff until it percolates into the soil.

To function properly a site must have permeable soils and adequate (at least 2-4 feet) depths to bedrock and water table to allow percolation. When designing the basin, coarse particulates should be removed before allowing runoff to enter the basin to lessen clogging of soil pores. Using a combined detention-infiltration basin design which utilizes a modified riprap settling basin to trap coarse particulates is also an effective option. Design problems generally involve ensuring an even spread of flow over the basin floor; and handling a variety of storm intensities. A variety of design modifications exist to accommodate these problems (see Schueler, 1987 for further information).

Construction and maintenance costs for infiltration basins are slightly more than those for extended detention ponds, owing to the need to encourage infiltration. The primary disadvantages for their use include the need for high permeability soils, a backup drainage system in case of infiltration failure, failure due to soil freezing, and the potential danger of ground water contamination when used near public and private water supply wells.

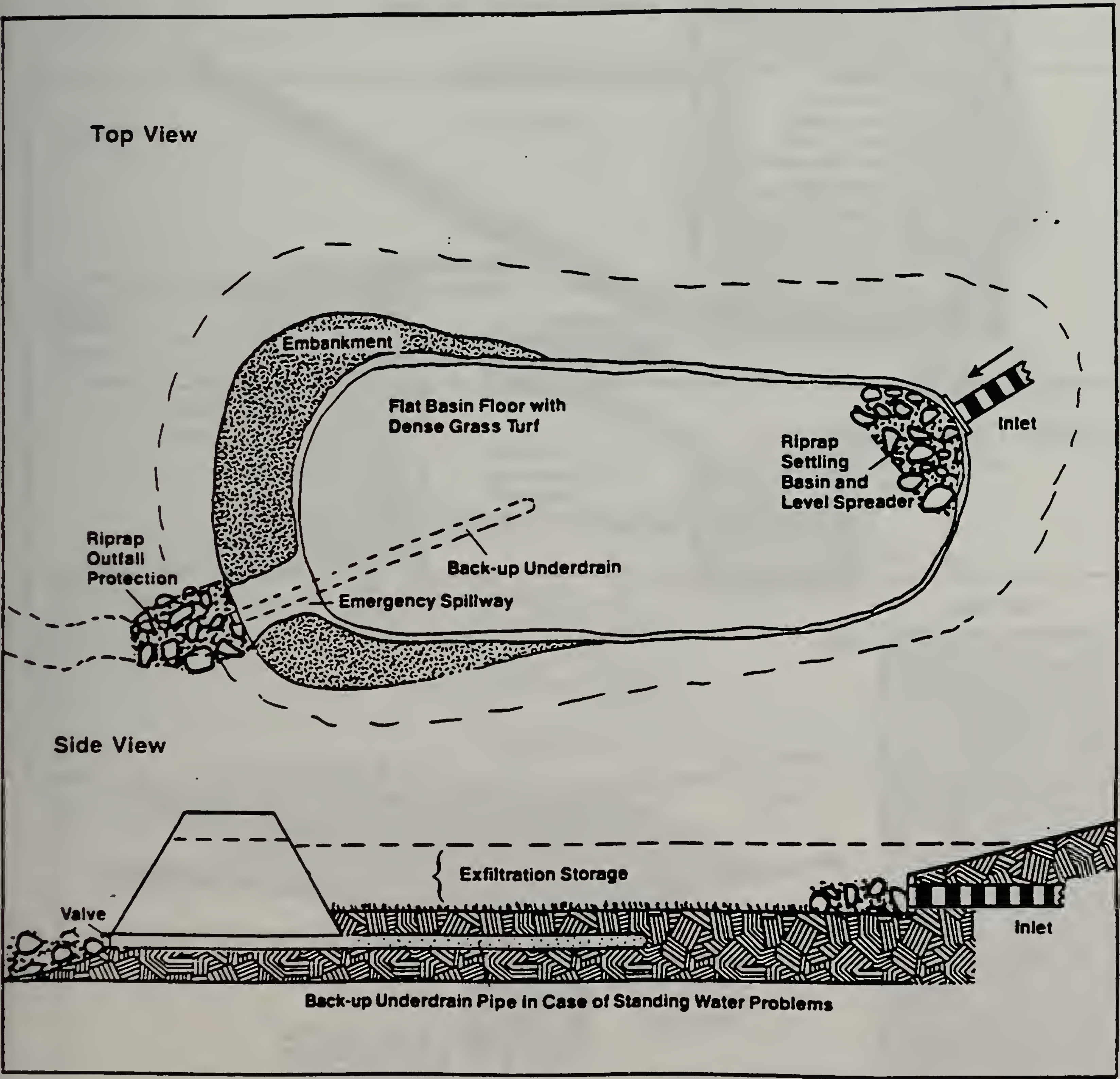
Infiltration Trench

Figure 4.6 presents a schematic of an infiltration trench. As for infiltration basins, trenches will quickly clog unless coarse sediments are removed from runoff prior to entering the trench. They are effective in removing fine suspended particles and dissolved pollutants. Infiltration trenches are a very flexible BMP because they can be tailored to a wide variety of runoff control situations.

Infiltration trenches can be a desirable option for reducing runoff-borne pollution from parking lots and roadways because of their minimal space requirements, easy construction and relatively low cost. Figures 4.7-4.9 shows several different trench systems.

Maintenance requirements and costs are generally moderate to high, but as for all infiltration structures, proper maintenance is essential for good performance. Disadvantages include need for high permeability soils and high cost for large scale runoff control situations (>10 acres).

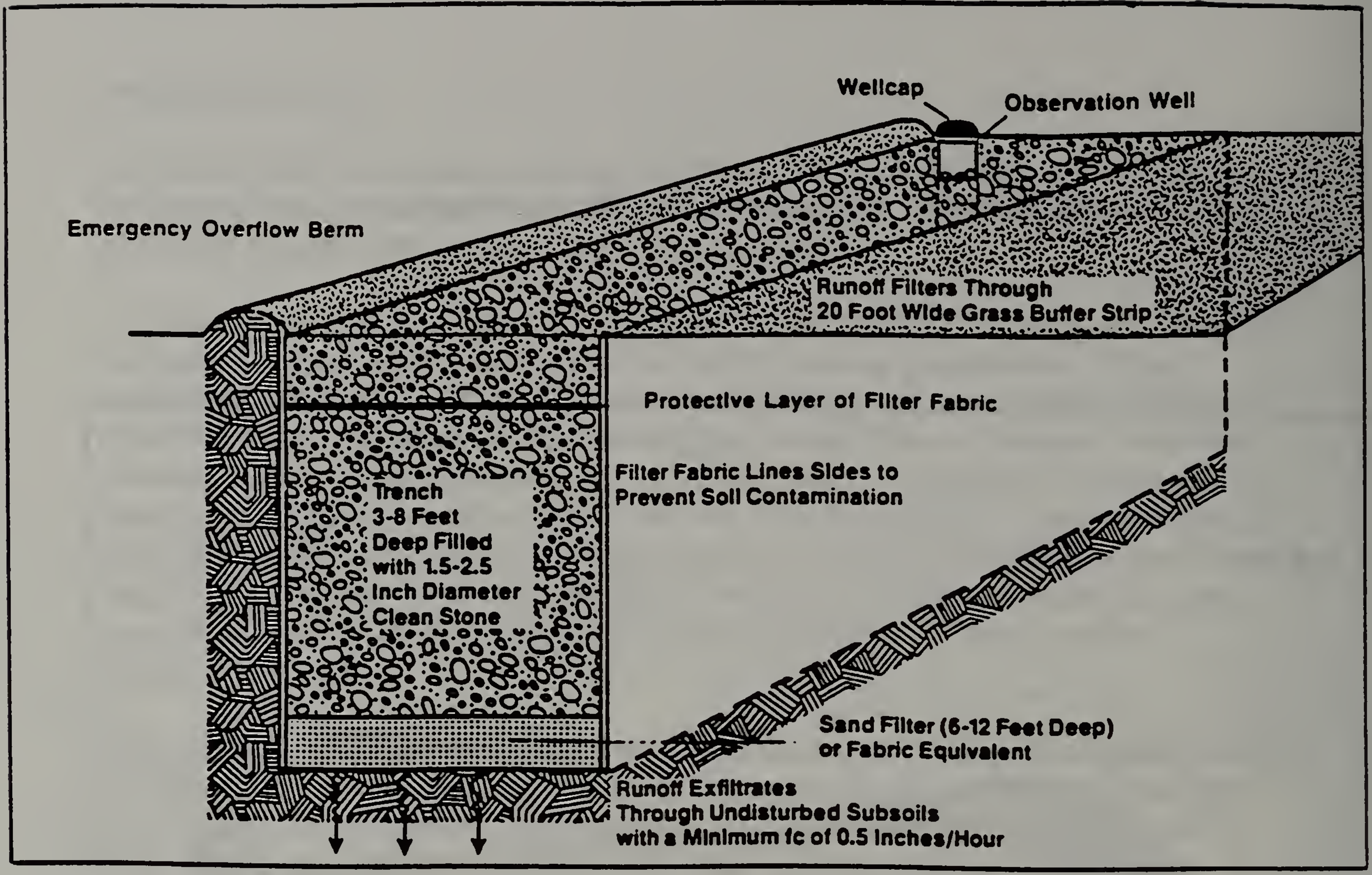
FIGURE 4.5 Schematic of Infiltration Basin



Top View
Embankment
Flat Basin Floor with Dense Grass Turf
Inlet
Riprap Settling Basin and Level Spreader
Riprap Outfall Protection
Back-up Underdrain
Emergency Spillway
Side View
Exfiltration Storage
Valve
Inlet
Back-up Underdrain Pipe in Case of Standing Water Problems

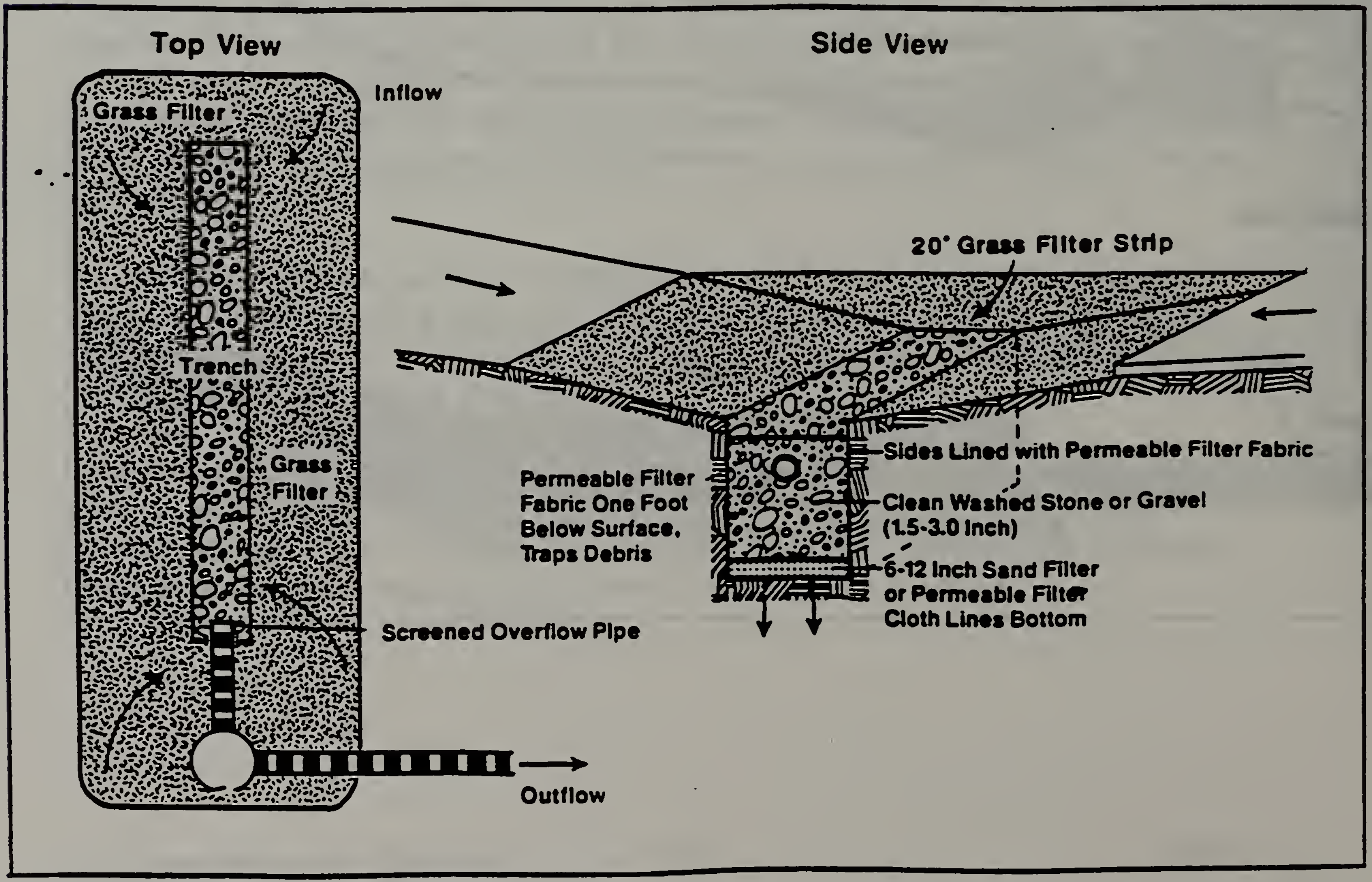
SOURCE: T.Schueler, 1987

FIGURE 4.6 Schematic of Infiltration Trench


Wellcap
Observation Well
Emergency Overflow Berm
Runoff Filters Through
20 Foot Wide Grass Buffer Strip
Protective Layer of Filter Fabric
Filter Fabric Lines Sides to
Prevent Soil Contamination
Trench
3-8 Feet
Deep Filled
with 1.5-2.5
Inch Diameter
Clean Stone
Sand Filter (6-12 Feet Deep)
or Fabric Equivalent
Runoff Exfiltrates
Through Undisturbed Subsoils
with a Minimum fc of 0.5 Inches/Hour

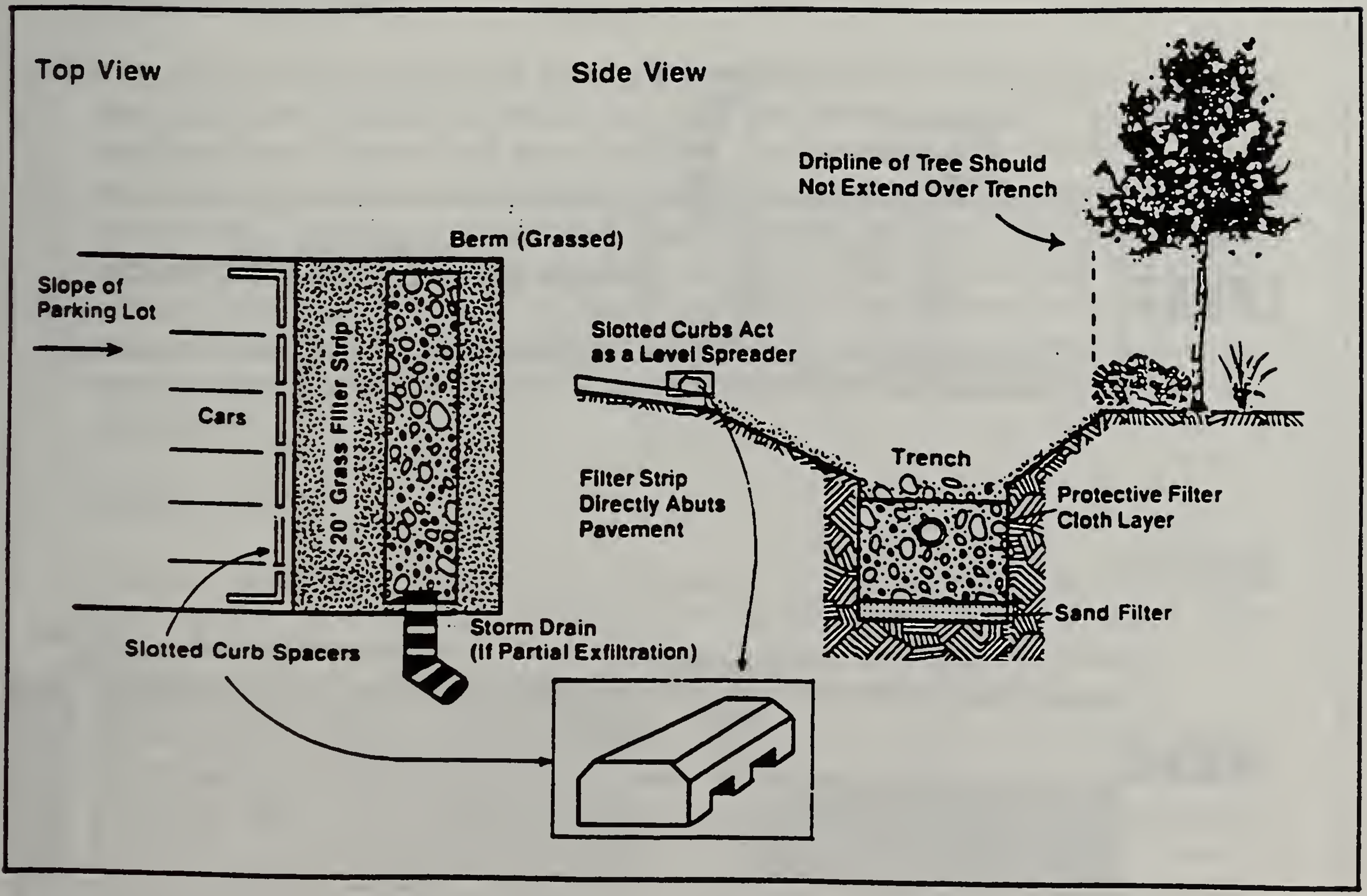
SOURCE: T.Schueler, 1987

FIGURE 4.7 Schematic of Median Strip Trench



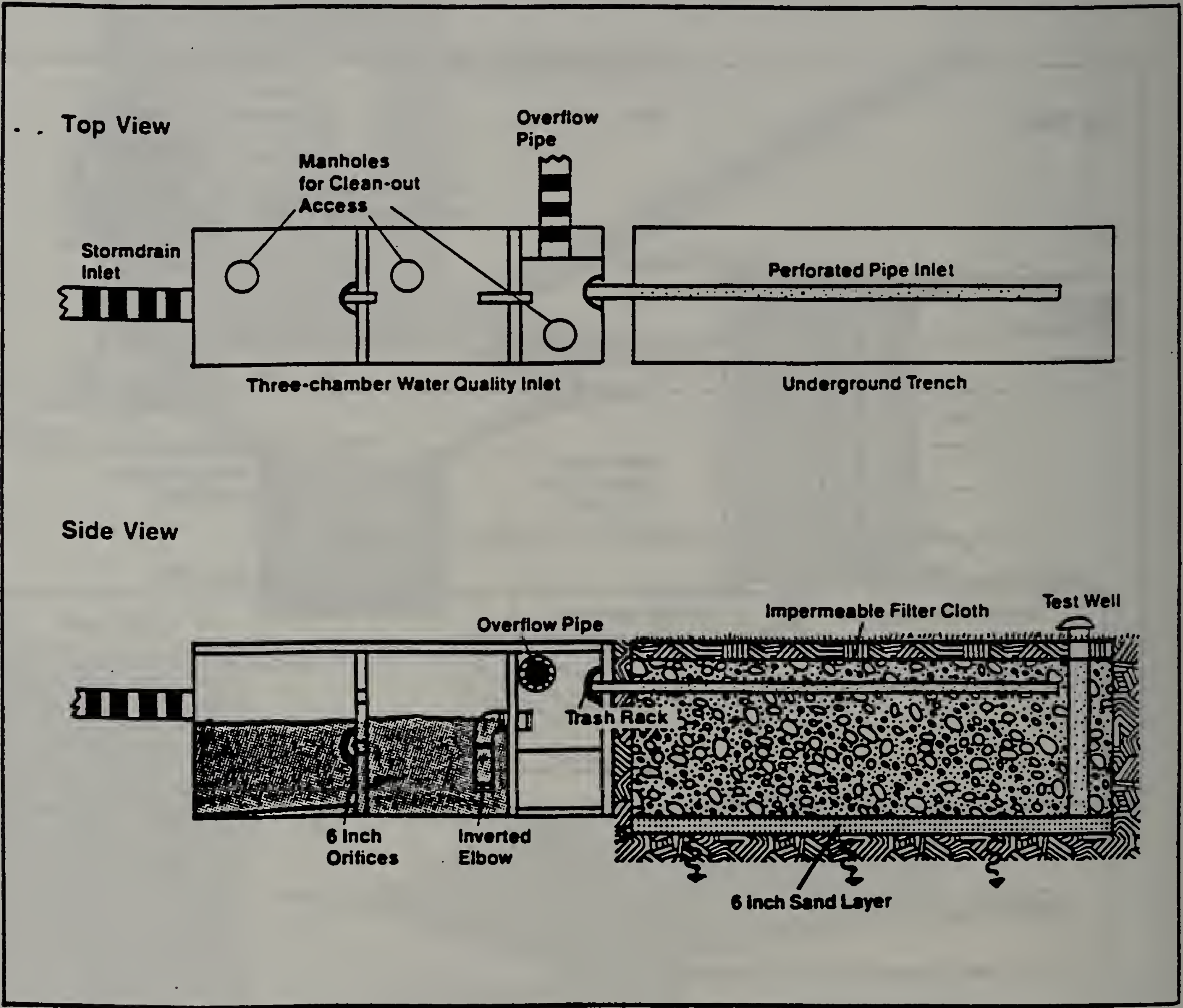
SOURCE: T.Schueler, 1987

FIGURE 4.8 Schematic of Parking Lot Trench


Top View
Side View
Dripline of Tree Should Not Extend Over Trench
Berm (Grassed)
Slope of Parking Lot
Slotted Curbs Act as a Level Spreader
20' Grass Filter Strip
Cars
Trench
Filter Strip Directly Abuts Pavement
Protective Filter Cloth Layer
Sand Filter
Storm Drain (If Partial Exfiltration)
Slotted Curb Spacers

SOURCE: T.Schueler, 1987

FIGURE 4.9 Schematic of Underground Trench with Oil/Grit Chamber



SOURCE: T.Schueler, 1987

Porous Pavement

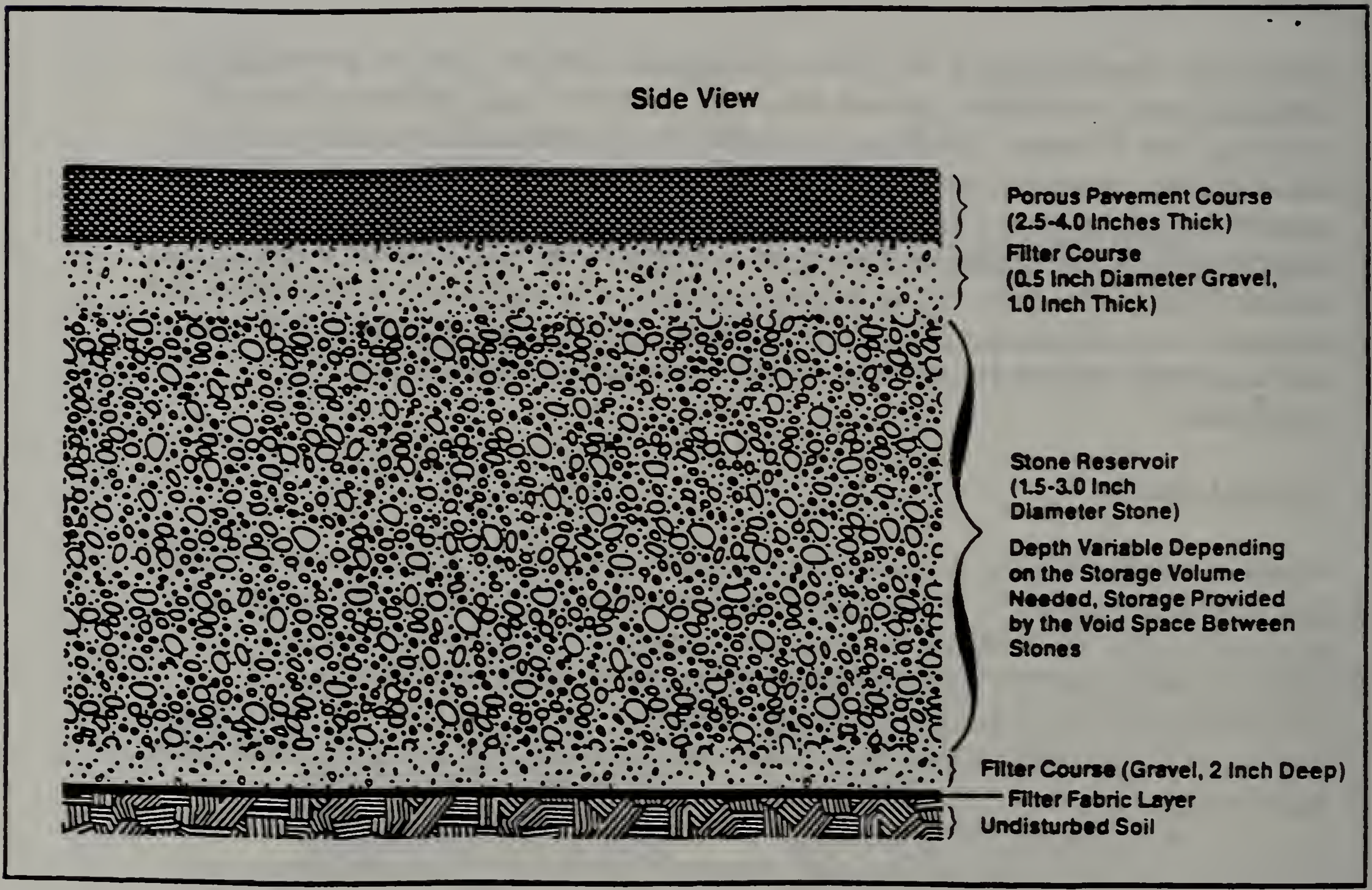
Porous pavements, if constructed correctly, can eliminate any need for further pollution treatment because they act to infiltrate precipitation into the ground before it has a chance to become surface run-off. As shown in Figure 4.10, the pavement must be constructed over permeable soils and are limited to gentle slopes to prevent run-off. However, it can remove both suspended and dissolved pollutants.

The major disadvantages of porous pavements are the need to prevent clogging from sediments carried onto the pavement, the tendency toward cracking due to freeze and thaw periods. The pavements are liable to clog if the roadway receives any eroded soil or sediments from the surrounding watershed. Likewise, it is unclear whether this pavement is a viable long-term option in the northeast due to its susceptibility for cracking due to winter cold. While the use of porous pavement offers many advantages: reduced land requirements, little or no need for curbs and gutters, and ease of maintenance, further research is needed to evaluate their use in the northeast.

Grassed Swales

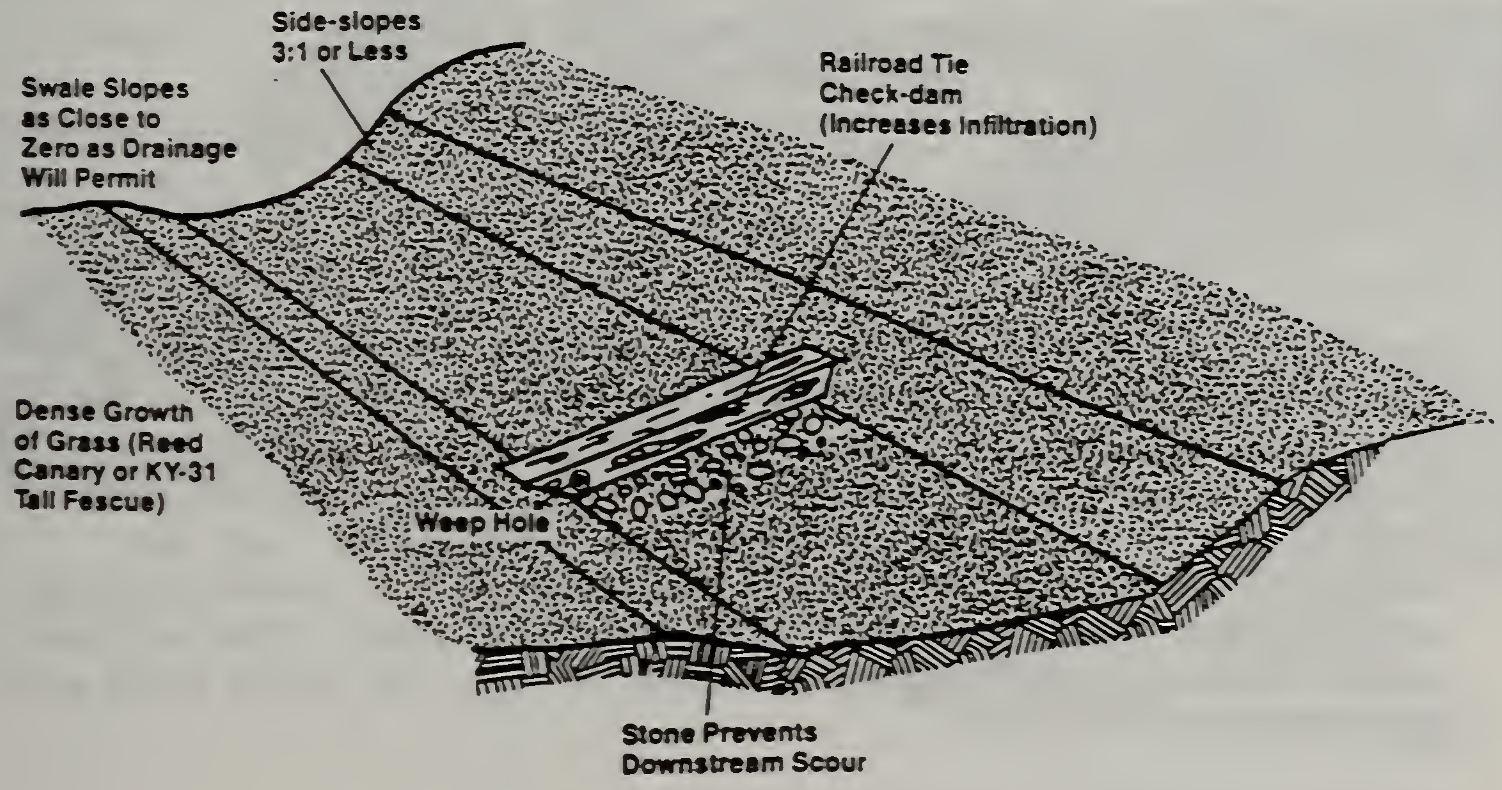
Grassed swales (Figure 4.11) are constructed, grass-lined channels that utilize flat slopes or grasses to direct runoff and remove particulates. In many cases, grassed swales serve as an alternative to standard curb-gutter drainage systems since they are generally less expensive and allow at least some stormwater infiltration and pollutant removal onsite. Swales aid to control peak discharges through reducing run-off velocities and allowing infiltration. However, the volume of infiltration is generally small. Grassed swales are capable of removing particulates from run-off, however, they are not effective in removing dissolved pollutants. Due to their limited capacity to provide infiltration and pollutant removal, grass swales are generally used in conjunction with additional run-off control measures for large developments.

FIGURE 4-10 Schematic of Porous Pavement


Side View
Porous Pavement Course (2.5-4.0 Inches Thick)
Filter Course (0.5 Inch Diameter Gravel, 1.0 Inch Thick)
Stone Reservoir (1.5-3.0 Inch Diameter Stone)
Depth Variable Depending on the Storage Volume Needed, Storage Provided by the Void Space Between Stones
Filter Course (Gravel, 2 Inch Deep)
Filter Fabric Layer
Undisturbed Soil

SOURCE: T.Schueler, 1987

FIGURE 4-11 Schematic of Grassed Swale



SOURCE: T.Schueler, 1987

Constructed Wetlands

Wetlands are generally constructed onsite as an extension to retention and detention ponds. When properly designed and constructed, man-made wetlands mimic a natural wetland's ability to remove large amounts of dissolved and suspended materials from run-off flow. Constructed wetlands are generally very successful at handling stormwater run-off generated onsite, but are expensive to construct and maintain. Figure 4.12 presents a development which utilizes a constructed wetland.

A summary of the pollution reduction benefits of various runoff control structures is provided in Chapter 2 of the book, "Controlling Urban Run-off: A Practical Manual for Planning and Designing Urban BMPs" by Thomas Schueler, Department of Environmental Programs, Metropolitan Washington Council of Governments. A copy of this section is included in this course manual.

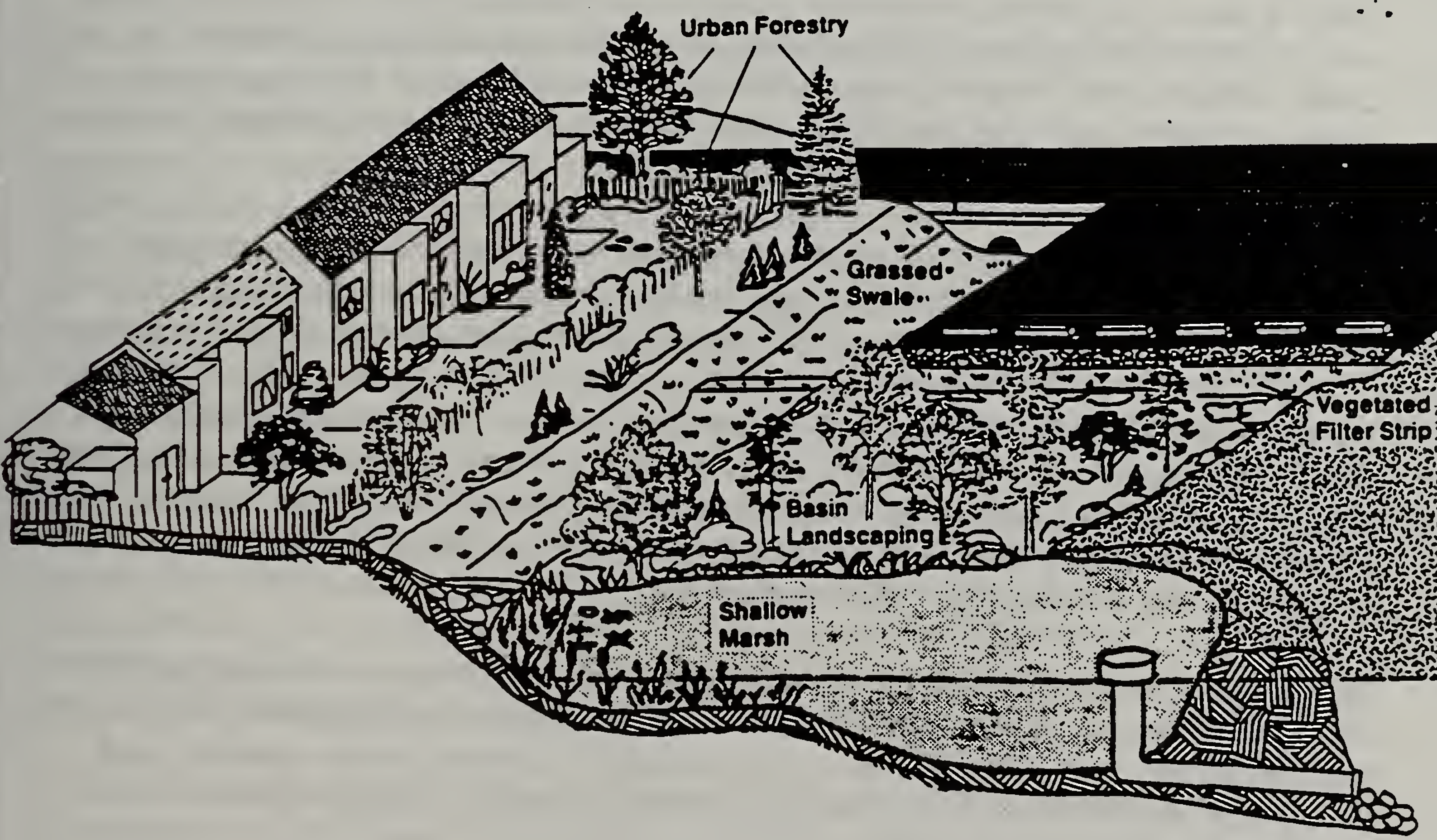
2. Wastewater

Septic systems are often a source of water pollution. Sewage effluent may enter lakes through ground water or surface water run-off. In lakes where groundwater represents a significant amount of water input, sewage from properly functioning septic systems may be a significant source of nutrient loading. If septic systems are not maintained, such that that it fails and sewage backs up at the land surface, effluent may travel in overland run-off, conveying nutrients, bacteria and viruses to the lake system. DEM staff may control nutrient loading from septic systems through their proper siting and maintenance.

Septic System Siting and Maintenance

Septic systems may be sited to minimize the potential for nutrients, bacteria and viral loading to lakes. In freshwater systems, minimization of phosphorus loading will probably be most important, while in estuarine systems, the extent of nitrogen loading may be of greatest concern. However, nitrogen is a concern for human health as well as surface water quality. In cases where wells are used for drinking water, elevated nitrate-nitrogen levels can cause an illness variously known as infant cyanosis, methemoglobinemia or "blue-baby syndrome" in infants, caused by the alteration of hemoglobin and subsequent problems with oxygen transport. In addition, high nitrate-nitrogen levels have been linked to the formation of carcinogenic nitrosamines. Therefore, it is appropriate to limit the levels of both phosphorus and nitrogen loading to groundwater in parks.

FIGURE 4-12 Schematic of Constructed Wetland



SOURCE: T.Schueler, 1987

While nitrogen moves fairly easily in ground water, phosphorus is more effectively adsorbed to soils. Therefore, the distance which phosphorus will travel in ground water tends to be less than that of nitrogen. Limnological studies documented by EPA have shown that the primary source of phosphorus is within 100 meters or approximately 300 feet of the shoreline of lakes. When systems are placed further than 100 meters from a lake or pond, phosphorus is more likely to be attenuated in the soil and is less likely to reach a lake. Therefore, wherever possible, within the ground-water recharge area, septic systems should be setback 100 meters from lakes and ponds. In cases where there is insufficient information to delineate a lake's ground-water recharge area, park staff may wish to set a conservative setback of 100 meters around the entire periphery of a lake.

The impacts of nitrogen loading are less easily controlled due to nitrogen's high mobility. To minimize nitrogen loading, wherever possible, septic systems should be placed outside of the ground-water recharge area to a lake.

Bacteria and viruses can also travel in ground water. In areas where the depth to ground water is shallow and flow velocity is approximately 1 foot per day, viruses have been found to migrate up to 100 total feet. The Town of Gloucester currently requires that septic systems be setback 300 feet from coastal waters to minimize the viral loading.

Septic systems should also be regularly maintained to ensure that they will function properly. To ensure that systems are properly maintained, it is recommended that the DEM set up a schedule to inspect septic systems, and pump and repair them if necessary. Cost for pumping a septic system generally range from $50-$100.

Wastewater Performance Standards

One means of limiting park capacity may be based upon the generation of nutrients from wastewater loading. Using the buildout and nutrient loading analysis, park staff can estimate the level of existing and future nutrient loading to the lake which will be generated by park use and private development in the watershed. In cases where the level of existing or future use which is programmed by the park management plan and community zoning controls will exceed the water's nutrient carrying capacity, the DEM and its abutting communities in the watershed may consider adopting maximum wastewater loading performance standards for future development.

Small Sewage Treatment Plants (SSTPs)

Small sewage treatment facilities (SSTFs) provide an alternative means of handling wastewater in parks which sustain high levels of use. SSTFs are typically used in areas where site conditions are not suitable for septic systems or where a large volume of wastewater must be handled (such as > 15,000 gallons per day). The cost of a SSTF may range from $300,000 to two million dollars.

The use of SSTFs would lend advantages and disadvantages to DEM staff. The advantage of SSTFs is that they provide a higher level of wastewater treatment than septic systems. Most SSTFs provide secondary or tertiary treatment of sewage, such that when properly operated and maintained, SSTFs release a higher quality effluent than septic systems (See Figure 4.13). The disadvantage of SSTFs is that their track record is unknown. Most SSTFs currently used in Massachusetts are relatively old (10-20 years) and do not represent state-of-the-art design. While problems have been experienced with many older systems, most newer state-of-the-art systems are operating successfully. The question is how will these newer systems function over time? The answer is not known. The risk of failure with a SSTF is greater than that of a gravity flow septic tank since SSTFs are subject to mechanical and electrical breakdown. If a SSTF failure occurs, wastewater may either be stored until treatment is assured, or untreated wastewater may be released to groundwater. The release of a large volume plume of wastewater to a nearby waterbody may be devastating. Therefore, it is recommended that their proper maintenance be assured if they are to be used.

A Generic Environmental Impact Report (GEIR) is currently being prepared to assess the impacts and implications of SSTFs. Copies of the Draft GEIR may be obtained from Mr. Martin Pillsbury at the Metropolitan Area Planning Council.

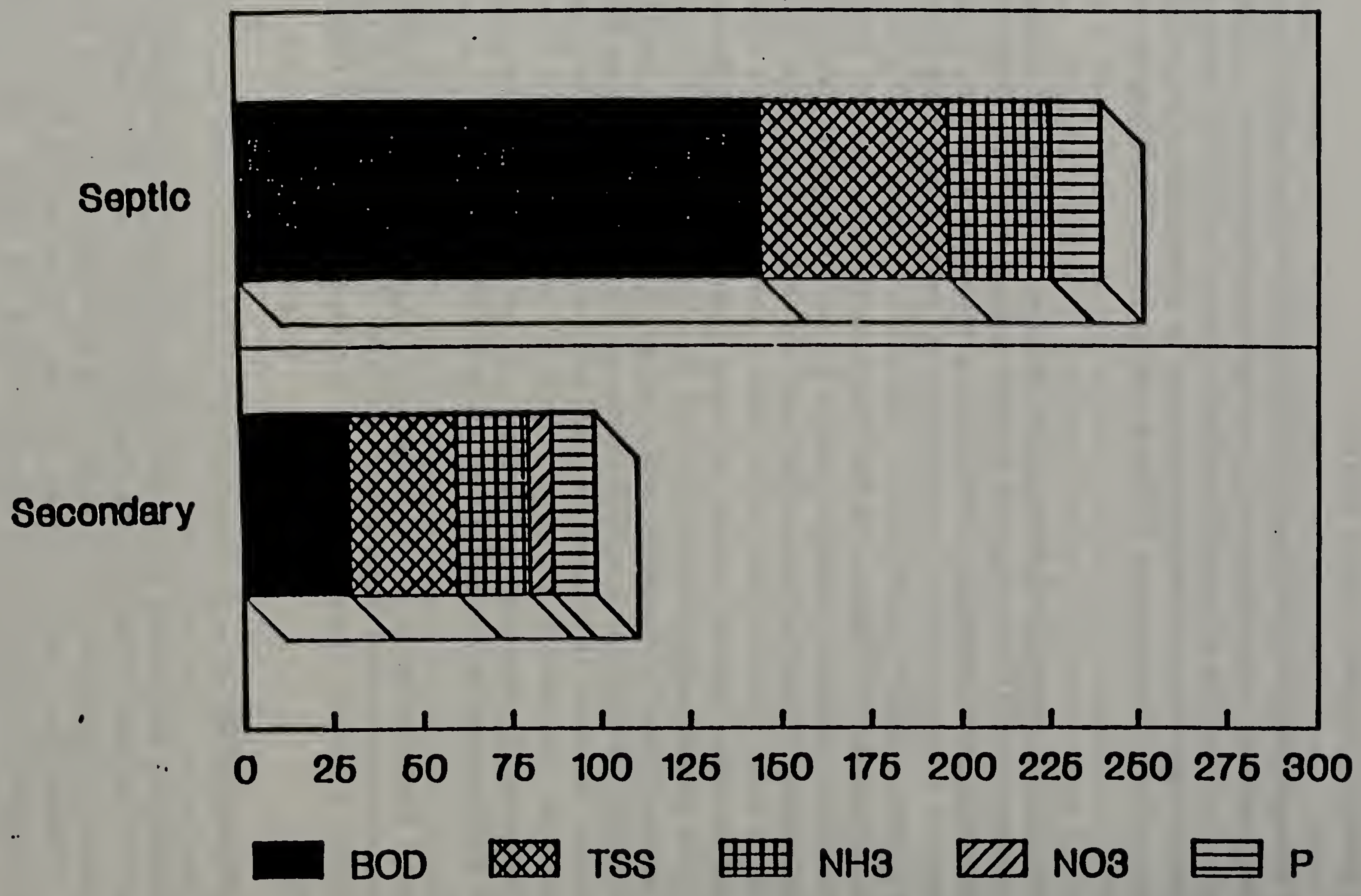
Composting Toilets

Composting (or dry) toilets are an alternative design which decreases the demand for both water supply and wastewater disposal. Title V allows a 40% reduction of design sewage flow to leaching facilities if composting toilets are used, provided that it can be proven that the site can handle the total sewage load if composting toilets fail or are removed in the future. The remaining 60% of the wastewater (referred to as grey water) must still be discharged utilizing conventional septic systems. Retrofitting existing toilets with composting toilets could actually reduce design wastewater flows.

FIGURE 4.13

SEPTIC vs. SECONDARY TREATMENT

Typical Effluent Quality (mg/l)



• Values from EPA

SOURCE: ICF Inc., et. al. 1990. Draft Generic Environmental Impact Report on Privately Owned Sewage Treatment Facilities (PSTFs).

One of the more common commercial composting toilets is the Clivus Multrum which has been used extensively in Europe and to a lesser extent in the United States. Cost estimates for Clivus Multrum systems is approximately $3,000-$5,000 per home.

The advantages of composting toilets include water conservation, decreases in wastewater flows, reduction in contaminant loadings to ground water and usable compost for gardening. The disadvantages include greater maintenance requirements than is associated with conventional systems, approval is required from DEP regulatory officials under Title V.

Solar Aquatics

This technology utilizes the natural ability of aquatic bacteria plants and animals to metabolize wastewater constituents combined with a greenhouse environment to provide year-round function. Wastewater passes through a series of tanks containing aquatic plants and fish which metabolize the wastewater constituents. The final wastewater effluent is reported to be of drinking water quality.

A pilot project is being conducted on a small scale facility with Massachusetts DEP utilizing solar aquatics for septage treatment in the Town of Harwich. Septage refers to pumpings from conventional septic systems. The results of this study are not expected for approximately 18 months. HWH has been retained by the Town of Harwich to undertake a hydrogeologic evaluation of the expansion of this facility.

Even if this project is successful, it does not mean that solar aquatics would be allowed for sewage treatment, as the study only evaluated septage treatment. For sewage treatment, an additional pilot project would be needed.

Given the initial successes of this form of treatment, it may be feasible to apply solar aquatic treatment of sewage effluent within the lake watershed in the future.

3. Shoreline Protection

The protection of shoreline areas is an important element in maintaining the water quality and ecological value of a lake or pond. Natural shoreline vegetation serves to contain and slow surface runoff providing for greater infiltration and attenuation of nutrients, heavy metals, hydrocarbons, and other contaminants. Shoreline vegetation also acts to stabilize the land, thereby reducing erosion. Shoreline areas provide critical habitat and travel corridors for a variety of upland species, and along tributaries to lakes, shoreline vegetation may serve to sustain a greater diversity of coldwater and warmwater fish species. Overhead tree canopies may shade the water, thereby providing a colder environment for fish species which are less tolerant of high water temperatures during summer months. Due to the tremendous value of the shoreline vegetation, it is recommended that the intensity of use in these areas be limited.

Shoreline protection in state parks may include the following elements:

a. wherever possible, prohibit the disturbance of natural shoreline vegetation to minimize the discharge of stormwater and its associated contaminants to lakes, and to maintain wildlife habitat;

b. provide a limited number of supervised lakeshore access points to lessen damage to shoreline areas;

c. in cases where the DEM only possesses partial shorefront property ownership; seek to acquire shorefront property or conservation easements around lakes;

d. prohibit off-road vehicles immediately adjacent (<15 feet) to the lake;

e. wherever possible, more intensive park uses such as campsites and ballfields should be clustered away from the lake edge.

4. Lawn Areas

Applications of fertilizers, herbicides and pesticides by DEM staff to park lawns and playing fields can function as sources of nitrogen, phosphorus and pesticide pollution to ground and surface waters. Pollutants may be transported to the lake or pond either directly, via surface run-off, or indirectly, via leaching to ground water. The amount of pollutant that ultimately leaches into ground water and surface water is a function of the type of ground cover, soil characteristics, climate, type of fertilizer used, application rate, and the degree of irrigation and rainfall (refer to Section II). Pollutant transport is also affected by all of the stormwater control methods described above and by the use of Best Management Practices during application.

DEM staff can minimize impacts to lakes and ponds from fertilizer use through a number of methods. Application of "slow-release" fertilizers is preferable to applying the more traditional water-soluble fertilizers because the compounds used in slow-release fertilizers compounds are much less prone to leaching. Other fertilizer BMPs include:

a. Consult weather forecasts before application. Do not apply fertilizers immediately before rain storms.

b. Restrict or eliminate fertilizer use near lake and pond shores, especially on steep slopes known to produce direct runoff into the water body.

c. Adopt soil conservation landscaping practices which reduce runoff flow velocities and prevent or reduce sheet or channel flow to lakes.

d. Leave natural vegetation within 100 meters of the waterbody to intercept runoff flow and assimilate nutrients.

e. Maintain a 100 meter phosphorus buffer zone around the shoreline.

f. Leave turfgrasses with heights of two or more inches. Taller grasses slow surface water runoff; they also appear thicker and greener between mowings.

Most pesticides, fungicides and herbicides are toxic to aquatic and terrestrial plants and animals (see Section II). The US EPA has mandated that each pesticide label provide toxicity information, including application warnings, for aquatic organisms at risk. Given the greater risks associated with pesticides, greater caution and care are required when applying these substances. In addition to the Best Management Practices recommended above for fertilizers, DEM staff are recommended to adopt the following BMPs:

a. Know the sensitive receptors (populations or species at risk) for each pesticide used, including those life stages (larva, egg, juvenile, adult, reproductive phase, etc.) which are at most risk. Prohibit or restrict application when those life stages at greatest risk are abundant.

b. Review all pesticides currently in use and compare with others available on the market which are less toxic to sensitive species or populations.

c. Require that all applicators be licensed and undergo periodic training.

d. Store and mix all pesticides away from water bodies in a "safe" area, preferably a well-ventilated storeroom which has a watertight floor slab. Floor drains should be sealed, or should direct drainage to a holding tank.

e. Prohibit spraying near shorelines.

f. Develop and implement an Integrated Pest Management strategy which minimizes pesticide use yet accommodates the special concerns of DEM lakes and ponds.

5. Construction Controls

Construction activities typically result in extensive clearing of land, leading to the erosion of soils during storm events, as sediment is carried with runoff to nearby water bodies. Sedimentation and erosion control techniques should be used to lessen the amount of sedimentation during construction. These techniques typically include:

a. using control structures to retain any sediment generated within the area of land disturbance. Control structures may include the placement of hay bales, siltation fences, mulch, or detention basins (see Figure 4.14).

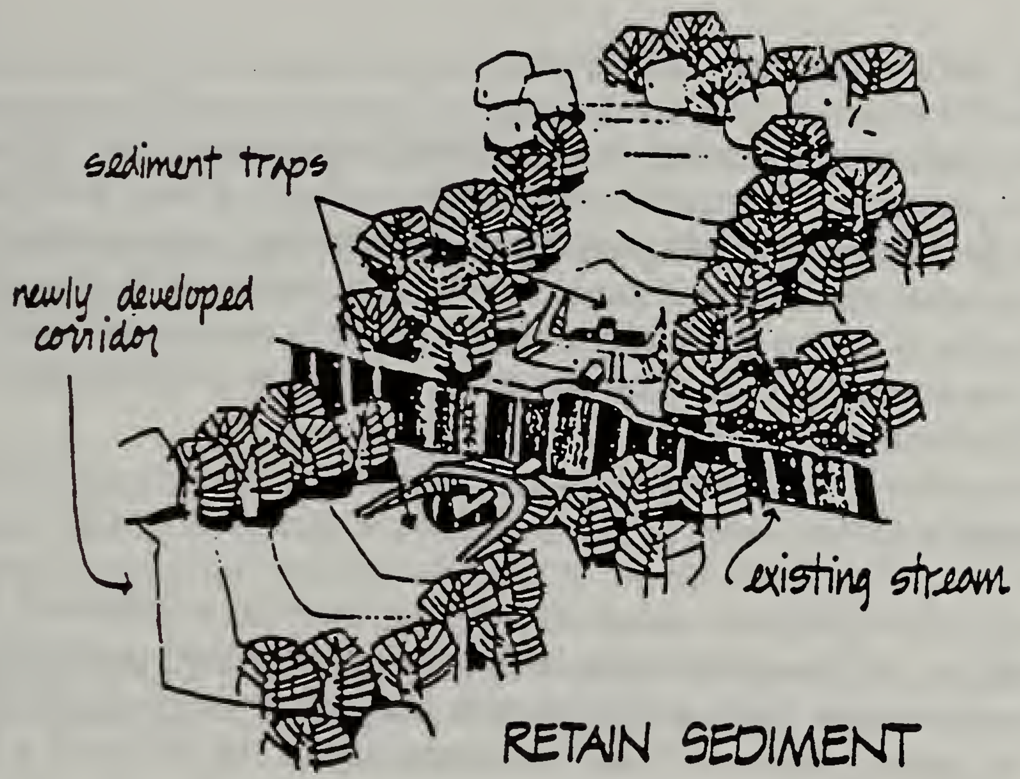
b. diverting runoff from slopes that are exposed during construction through constructing a dike, berm and/or ditch (see Figure 4.15).

c. preparing an erosion and sedimentation control plan which specifies the design and placement of control structures.

d. using ground cover to stop erosion after construction. Grasses and legumes are the species most commonly used to stabilize slopes. Vegetation may be established through seeding or sodding.

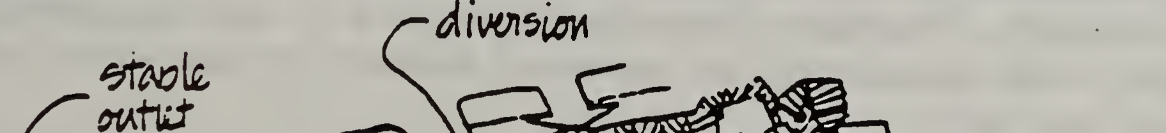
e. minimizing the extent of land disturbance through phasing construction activities. Land clearing for subsequent development phases should not occur until a prior area has been constructed and is reseeded.

FIGURE 4.14 Sedimentation Control Structures



SOURCE: U.S.D.A., Soil Conservation Service. Vegetative Practices in Site Development. Massachusetts Conservation Guide. Volume II.

FIGURE 4.15 Runoff Diversion during Construction Activities



SOURCE: U.S.D.A., Soil Conservation Service. Vegetative Practices in Site Development. Massachusetts Conservation Guide. Volume II.

Monitoring

Lake and watershed monitoring is an essential element of any lake management program. Regular water quality sampling and analysis is necessary to detect water quality changes. In addition, monitoring of stormwater control devices and septic systems is essential to ensure that watershed impacts in the park are minimized. It is recommended that a systematic monitoring program be set up at each state park to detect changes before they become a problem.

Public Education

Many sources of pollution to lakes and ponds may be minimized through public education. Through the use of signage, pamphlets and interpretive programs visitors may learn why the park use rules which are in place are necessary. As people become better educated about the value of a lake and its ecosystem, they are more likely to respect its sensitivity and to treat it accordingly. It is recommended that the DEM develop interpretive programs, pamphlets and signage which discuss lake and watershed use problems such as user conflicts, illegal dumping, etc.

Use Controls

The physical use of a lake and its watershed may have a significant impact on a lake's quality. Therefore, the ecological impacts of each use should be weighed when determining the types and intensity of uses which will be allowed in a park.

Motorized Boating

There have been relatively few studies on the impact of boat engine pollution. Most reports which have been completed have focused on the effect of two-cycle outboard engines. These older engines were manufactured prior to 1972. Newer engines are designed to use fuel more efficiently and do not release as much fuel to water. Once petroleum hydrocarbons are released to the water, they may concentrate at the water's surface, remain suspended in the water column, or settle to the bottom. Petroleum discharged in a lake's surface waters and in its water column usually disappears rapidly, however, hydrocarbons which reach a lake's sediments may last for years.

The primary documented effects of boat engines are odor, an off taste in fish, and toxic effects on marine organisms. An EPA/Boats Industry Study completed in 1974 noted an odor threshold at 3 ppm (3 gallons fuel burned per million gallons of water) and an off taste at 110 ppm. However, further research is needed to determine the impacts of the newer, more efficient boat motors which are manufactured today.

The Massachusetts MDC and DEP generally prohibits motor boating in public drinking water reservoirs.

Swimming

The most desirable areas for swimming are clear water lakes with relatively few weeds, hard sandy bottoms, and a relatively gradual depth contour. Therefore, ideal swimming conditions tend to occur in oligotrophic lakes.

Massachusetts MDC and DEP generally prohibits swimming in public drinking water reservoirs due to the potential for sewage release.

Off-Road Vehicles

The improper use of off-road vehicles (such as dirt bikes and snowmobiles) have led to erosion in shoreline areas. For this reason, these uses are often prohibited in areas immediately adjacent (<15 feet) to lakes. Where this is not possible due to political and social demands, well defined and marked trails should be created to direct their use to less sensitive areas which may be more readily supervised.

Forestry

Forestry activities occur in many of the DEM's parks. If forestry activities are improperly conducted, they may lead to serious problems of land erosion and sedimentation to nearby waters. Heavy sedimentation may impact wetlands, streams, and lake and pond habitat and their associated wildlife, as well as the aesthetic value of these systems.

The USDA Soil Conservation Service (SCS) has developed standards, or best management practices (BMPs), for forest land erosion control. These BMPs apply to all disturbed forest land areas including logging roads, skid roads and loading areas; buffer or filter strips; slash disposal areas; site preparation; and burned and overgrazed areas.

Key elements of the standards include:

1. providing vegetative cover on all disturbed areas.

2. maintaining filter strips (buffers) of undisturbed vegetation along streams, rivers, lakes, ponds and wetland borders;

3. utilizing proper truck road and skid road design and maintenance;

4. ensuring that necessary steam crossings occur at right angles to the direction of flow and at points where the stream is narrow and flow is low; and

5. minimizing sedimentation through properly placing and maintaining control measures such as silt fences, hay bales and sediment traps.

According to Mr. Dun Lethele, soil scientist at the Middlesex County SCS office, in the northeast, most forest land erosion comes from skid trails and logging roads. Properly constructed roads and adequate maintenance after logging is the best way to prevent siltation from forestry activities. A copy of the SCS's "Standard for Forest Land Erosion Control" is included in this section for your review. Please contact your local SCS office to obtain further information about erosion and sedimentation control.

Park Planning/Goals Program

The Department of Environmental Management launched a program in 1983 to establish guidelines for operations and land stewardship (GOALS) of the state's parks. As a part of this program, DEM foresters, landscape architects and planners are developing GOALS for every state forest and park in the form of management plans. Each management plan will spell out the objectives for the park's management, expansion, use and protection. Approximately 15 management plans are now complete. "Zoning" in this case is intended to denote park use and management categories and differs from the regulatory land use zoning adopted by communities under the authority of MGL Chapter 40A, The Zoning Act.

The GOALS program involves four elements:

1. Land Stewardship Zoning

Massachusetts' forests and parks serve many purposes, including the protection of sensitive resources, areas of active and passive recreation, and areas of timber management. The appropriate use of each area is "zoned", or categorized, under this program to ensure their appropriate management.

2. The Team Approach

The GOALS for each park and forest are developed by a team of park and forestry management and planning professionals to ensure that all of the park's various needs are recognized. In addition, the DEM team works with a Citizen Advisory Council throughout the planning process. The Citizen Advisory Council is comprised of local residents, local officials and representatives of organized user groups such as hunters, fishermen or trail bikers. The DEM normally meets monthly with the Citizen Advisory Council to gain local feedback and direction during the planning process.

3. Issue and Opportunity Identification

The GOALS program is intended to point out conflicting demands for the use of the state's parks and forests, and identifies current and anticipated management problems. Based upon each park's opportunities, demands and problems, strategies for its future use are developed.

4. Action Recommendations

Recommendations are made for the future management of each park and forest.

At the heart of the GOALS program is its zoning. Through the GOALS process, land is zoned into four general categories: 1) Unique Resource Zone, 2) Environmental Protection Zone, 3) Natural Resource Management Zone and 4) Developed Lands Zone. The Unique Resource Zone would include areas requiring a high degree of protection, such as rare species habitat or historic sites. The Environmental Protection Zone would include sensitive areas such as wetlands, steep slopes, and other areas in need of protection from inappropriate use. The Natural Resource Management Zone would include areas where both dispersed recreation and resource protection may be accommodated, and the Developed Land Zone would include areas which can sustain relatively high use levels. The Developed Land Zone would typically contain areas designated for active recreation, visitor's centers, and administration and maintenance facilities. The park uses which are allowed within each of the four zoning designations is standard and is consistent throughout the state.

The GOALS program provides a format whereby DEM may maximize watershed protection to its lakes and ponds on state lands. Based upon each lake's features and watershed characteristics, the zoning designations could be used to cluster more intensive park uses away from the lakeshore edge, and to minimize the amount of heavy recreational use allowed in sensitive habitats. For example, areas which are critical to lake functions, such as its associated wetland areas and shorelines (buffer zones), may be zoned "Environmental Protection" or "Natural Resource Management," depending upon particular site characteristics. Lakes which support valuable endangered species habitat or which contain archaeological resources would be zoned "Unique Resource." A careful review of the existing conditions of the DEM's surface waters and their watershed is needed to weigh the demand for various water and land uses against their potential impacts. The GOALS program may also provide a forum for initiating discussions with each park's bordering communities about adopting regulatory tools for water quality protection and initiating a land acquisition program.

DEM-Community Coordination

The DEM should recognize that in most cases the watersheds of its lakes are shared, and the Department is limited in what it alone can achieve in maintaining water quality. Therefore, the DEM should explore ways to work with its neighboring communities to adopt regulations aimed at minimizing the impacts of land development throughout the entire watershed to its lakes.

DEM Training

The continued education of DEM staff is essential to achieving a successful lake management program. The information which has been discussed in this course must now in-turn be imparted to the professionals in DEM who make decisions about park use. Therefore, it is recommended that a lake management training session be set up to ensure that what has been taught this week does not end in the classroom. In addition, lines of communication must be developed between the various disciplines in DEM to better utilize the Department's skills.

PERMITTING REQUIREMENTS

Introduction

All work in waterbodies or in their tributaries, outlets or bordering wetlands is subject to regulatory review. The scope of a proposed project defines the regulatory requirements that must be complied with. There are three regulatory levels: local, state and federal. Some environmental laws originate ion the state, but are locally implemented. In many cases, issuance of some permits is dependent upon successful review and issuance of other related permits. The more complicated a proposed project is, the more complicated and intricate the regulatory flow chart becomes. The following sections briefly introduce the key regulations, criteria and timing for successful lake remediation, development and maintenance strategies. Tables 4.4 through 4.6 summarize each of the regulations described in this section.

Permits Required for Typical Restoration and Maintenance Plans

Local Permits

In accordance with Massachusetts Home Role Provisions each city and town in the Commonwealth may enact local zoning, board of health and resource protection ordinances, bylaws and regulations. Depending upon the type of work proposed and the locality in which a waterbody is located, different levels of local regulatory review may be triggered. Three agencies that may regulate work relative to lake or pond management are discussed below.

1. Conservation Commissions

Jurisdiction: Any work in, over or adjacent to waterbodies, wetlands, rivers, streams within municipality.

Authority:

- Massachusetts Wetlands Protection Act
  MGL Chapter 131, Section 40
  310 CMR 10.00
- Local Wetlands Ordinances or Bylaws

TABLE 4.4

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

LOCAL

	CONSERVATION COMMISSION	BOARD OF HEALTH
Purpose	•Protection of water resources •Avoid or minimize impact to wetland functions	•Public health, safety & welfare •Accredation of bathing beaches
Statute	•MGL C.131, S.40 •Local bylaw or ordinance	•State Environmental Code: Title 5 MGL C.111, S.17 •State Sanitary Code, Chapter VII MGL C.111, S.127A
Regulations	•310 CMR 10.00 •Local regulations	•310 CMR 15.00 •105 CMR 445.00
Geographic Jurisdiction	•Activity in waterbodies, adjacent wetlands (as defined in the regulation), or 100 foot buffer zone	•Statewide subsurface discharges of less than 15,000 gpd to ground (i.e., septic systems) •Statewide water bodies
Permit	•Determination of Applicability •Order of Conditions	•Subsurface Sewage Discharge Permit •Accredited Bathing Beach License
Application Form	•Request for Determination of Applicability •Notice of Intent	•Town specific •Application for license to operate an accredited bathing beach
Fees	•Established at 801 CMR 4.00	•Determined locally

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

FEDERAL

	ARMY CORPS OF ENGINEERS	ENVIRONMENTAL PROTECTION AGENCY
Purpose	•General environmental concerns •Wetlands •Fisheries •Wildlife •Flood hazards •Navigation •Recreation •Water quality •Economics •Aesthetics •Land use	Protection of: •Water quality •Wetlands
Statute	•Rivers & Harbors Act •Clean Water Act of 1977 •Marine Sanctuaries Act	•Clean Water Act S.404 (b)(1)
Regulations	•33 CFR Parts 320-330	•40 CFR Parts 230
Geographic Jurisdiction	•Navigable waters & wetlands	•Navigable waters & wetlands
Permit	•Section 9 & 10/structures •Section 404/fill •Section 103/transport	•Findings of Compliance
Application Form	•Notice of Intent (same as wetlands Protection Program) or standard application	•Factual Determination
Fees	•None	•None

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

	STATE		
		DEPARTMENT OF ENVIRONMENTAL PROTECTION DIVISION OF WETLANDS AND WATERWAYS	
	MASSACHUSETTS ENVIRONMENTAL POLICY ACT UNIT	WETLANDS PROTECTION PROGRAM	WETLANDS RESTRICTION PROGRAM
Purpose	•Overall environmental impact review & impact minimization •Identification of issues, centralized information gathering	•Protection of water resources •Avoid or minimize impact to wetland functions	•Map all state wetlands at 1:5000 •Place deed restriction prohibiting certain activities
Statute	•MGL C30, S.61-62H	•MGL C131, S.40	•MGL C130, S.105 (coastal) •MGL C131, S.40A (inland)
Regulations	301 CMR 11.00	310 CMR 10.00	302 CMR 4.00 & 6.00
Geographic Jurisdiction	Statewide: •Requires a state action or permit •Threshold exceeded (as listed in 301 CMR 11.00) •Requires expenditure of state funds •An Area of Critical Environmental Concern (ACEC)	•Activity in waterbodies, adjacent wetlands (as defined in the regulation), or 100 foot buffer	Statewide: Wetlands •See list of cities & towns with Orders of Restriction
Permit	•Certificate of the Secretary of the Executive Office of Environmental Affairs	•Superseding (final) Order of Conditions if local order appealed	•Order of Conditions •Deed Restriction, Order of Restriction
Application Form	•Environmental Notification Form •Environmental Impact Report	•Notice of Intent	•Notice of Intent •Restriction Process
Fees	•none	•801 CMR 4.02	•801 CMR 4.02

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

STATE

DEPARTMENT OF ENVIRONMENTAL PROTECTION

	DIV. OF WETLANDS & WATERWAYS		
	WATERWAYS REGULATION PROGRAM	DIVISION OF WATER POLLUTION CONTROL	DIVISION OF SOLID WASTE
Purpose	•Protection of public rights of fishing, fowling & navigation through - navigation safety, structural soundness, promote public access, littoral property rights protection, natural resource protection, public facilities operation protection	Administration of •dredging material disposal •wetland filling •regulation of discharges of pollutants to surface and ground waters	•Proper disposal of dredged materials
Statute	•MGL C.91	MGL C.111, S5E	•MGL C.21A, S2&8 •MGL C.111, S150A
Regulations	•310 CMR 9.00	•314 CMR 9.00 •314 CMR 4.00	•310 CMR 19.00
Geographic Jurisdiction	•Filled tidelands •Mean high water line to 3 miles seaward •Rivers •Great ponds •Waterways that are fish runs •Waterways which have received public funds	•Wetlands •Waterbodies	•Landfill or disposal site accepting dredge materials
Permit	•Chapter 91 Waterways License •Determination of Applicability	•Water Quality Certificate •License to apply chemicals	•Request for Determination whether solid waste is a special waste per 310 CMR 19.061
Application Form	•Standard application •Request for Determination of of Applicability •Request for jurisdictional determination (informal)	•Standard application •Applicaton to apply chemicals	•Issuance of Written Determination
Fees	•310 CMR 9.16 (no fee for public agencies, including DEM)	•None at present	•None at present

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

	STATE		
		DFWELE	DEPT. OF ENVIRONMENTAL MGMT
	MASSACHUSETTS COASTAL ZONE MANAGEMENT	DIVISION OF FISHERIES AND WILDLIFE	OFFICE OF DAM SAFETY
Purpose	•All activities affecting coastal resources as stated in 27 MCZM Program Policies	1. Impose conditions regarding fisheries & wildlife interests 2. Protection of rare and endangered species	•Oversee safety of dams
Statute	•Federal CZM Act	1. MGL Chapter 132, S.42 & 48 2. MGL Chapter 131, S.40	•MGL C.253, S.44-50
Regulations	•301 CMR 21.00 •301 CMR 20.00 •15 CFR Part 930	1. None 2. 310 CMR 10.37 & 10.59, 321 CMR 8.00	302 CMR 10.00
Geographic Jurisdiction	•Designated coastal zone •All activities directly affecting coastal zone & exceeding thresholds listed in MEPA regulations	•Statewide	•Dams greater than 6 feet in height or which can store 15 AF of water or which upon breach could endanger property or public safety
Permit	•Federal Consistency Concurrence	1. Coordination with local Conservation Commission 2. Order of Conditions per 310 CMR 10.00	•Chapter 253 Permit •Certificate of Compliance or Non-compliance
Application Form	•Consistency Certificate & Federal Permit Application	1. Written notification 2. Appendix A to NOI	•Notice of Intent •Dam Registration Form
Fees	•None at present	1. None 2. 801 CMR 4.02	•None at present

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

STATE

		DEPT. OF FOOD & AGRICULTURE	
	MASSACHUSETTS HISTORICAL COMMISSION	MASSACHUSETTS PESTICIDE BUREAU	METROPOLITAN DISTRICT COMMISSION
Purpose	•Preserving historic or archaeological properties and resources	•Certification & licensing of applicators •Registration of pesticides & herbicides	•Prevention of pollution in MDC waters
Statute	•MGL C.9, S.26-27C	•MGL C.132B, S.6A&10	•MGL C.92, S.10-19
Regulations	•950 CMR 71.00	•333 CMR 2.00 & 10.00	•310 CMR 23.00 •350 CMR 8.00, 9.00
Geographic Jurisdiction	•Statewide	•Statewide application of pesticides and herbicides	•MDC Water per •310 CMR 23.01
Permit	•Determination of Effect	•Certification & License Document	•Written permit, legislation or special regulation
Application Form	•Project Notification Form or Environmental Notification Form	•Examination, application for certification or licensing	•Written notification
Fees	•None	•$25.00 - $50.00	•None

TABLE 4.5

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR WATERSHED MANAGEMENT TECHNIQUES

	LOCAL	STATE	FEDERAL
		DEPARTMENT OF ENVIRONMENTAL PROTECTION	
	PLANNING BOARD, ZONING BOARD	DIVISION OF WATER POLLUTION	ENVIRONMENTAL PROTECTION AGENCY
Purpose	•Land planning and development	•Surface and ground water discharges •Proper wastewater treatment	•Protection of water quality
Statute	•MGL 40A, 41	•Federal Clean Water Act •State MGL C.21, S.43	•Clean Water Act Section 301 & 402
Regulations	•Local •Zoning Bylaws •Zoning Map •Master Plan •Subdivision Control	•314 CMR 2.00, 3.00 & 5.00, 7.00	•40 CFR Parts 122-125
Geographic Jurisdiction	•Municipality	•Waters receiving discharges	•Waters receiving discharges
Permit	•Zoning approvals •Subdivision approval •Approval not required	•Permit for discharge proposed	•Natural Pollutant Discharge Elimination System (NPDES)
Application Form	•Specified in Zoning Bylaws •Specified in Subdivision Rules and Regulations	•Application for Permit to Discharge to Waters of the Commonwealth •Application for Permit to Discharge to Ground •Application for Permit for Sewer System Extension or Connection	•NPDES
Fees	•Established locally	•Established by Executive Office of Administration and Finance	•None

Note: All regulatory processes identified in Table 4.4 apply for watershed management as well. For ease in use of these tables, the regulations presented in Table 4.4 are not reproduced in Table 4.5.

TABLE 4.6 Activities and Potential Permits

						F&W			F&A					
	WPA	WRP	C. 91	DWPC	Sol. Wst.	R&E/Exot/DD	ODS	MHC	Pest. Bur.	MDC	DEP	MEPA	ACOE	EPA
PHYSICAL TECHNIQUES														
Benthic Screening	X	X								X	X	X		
Lake Level Drawdown	X	X	X	X		X X	X			X	X	X	X	
Dredging	X	X	X	X	X	X X		X		X	X	X	X	X
Harvesting	X	X				X				X	X	X		
Hydroraking	X	X	X	X		X				X	X	X		
Aeration	X	X	X	X						X	X	X		
Hypolimnetic Withdrawal	X	X	X	X			X			X	X	X	X	X
Sediment Oxidation	X	X	X	X						X	X	X	X	X
Dilution and Flushing	X	X	X	X						X	X	X		
Artificial Circulation	X	X	X	X						X	X	X	X	X
BIOLOGICAL TECHNIQUES														
Grass Carp	X	X				X X				X	X	X	X	
Pathogens	X	X				X				X	X	X	X	
Insect Pests	X	X				X				X	X	X	X	
Food Chain Manipulation	X	X				X				X	X	X	X	
CHEMICAL TECHNIQUES														
Herbicides & Algicides	X	X				X			X	X	X	X		
Alum	X	X				X				X	X	X		
Dye	X	X				X				X	X	X		
OTHER														

Regulations: The Massachusetts Wetlands Protection Act sets forth a public review and decision-making process by which activities affecting Areas Subject to Protection Under the Act are to be regulated in order to contribute to the following interests:

- protection of public and private water supply
- protection of ground water supply
- flood control
- storm damage prevention
- protection of land containing shellfish
- protection of fisheries
- protection of wildlife habitat

The purpose of the regulations is to define and clarify that process by establishing standard definitions and uniform procedures by which conservation commissions and the Department may carry out their responsibilities under the Act.

Local ordinances, bylaws or regulations may establish more stringent protection of wetlands or other natural resource areas (e.g. aesthetics, wildlife, soils, etc.).

The state regulations establish "Areas Subject to Protection Under the Act" and from these areas establish "Wetland Resource Areas." Additionally, activity proposed with one hundred (100) feet of a resource area which may alter an Areas Subject to Protection is subject to regulation as work within the Buffer Zone.

The following areas are subject to protection under the Act:

(a)	Any bank,		the ocean
	any freshwater wetland,		any estuary
	any coastal wetland,		any creek
	any beach,	bordering	any river
	any dune,	on	any stream
	any flat,		any pond
	any marsh,		or any lake
	or any swamp		

(b) Land under any of the waterbodies listed above
(c) Land subject to tidal action
(d) Land subject to coastal storm flowage
(e) Land subject to flooding

The definition of "Activity" and "Alter" are broad and will potentially result in the regulation of all lake/pond remediation and maintenance projects.

> *Activity* means any form of draining, dumping, dredging, damming, discharging, excavating, filling or grading; th erection, reconstruction or expansion of any buildings or structures; the driving of pilings; the construction or improvement of roads and other ways; the changing of run-off characteristics; the intercepting or diverging of ground or surface water; the installation of drainage, sewage and water systems; the discharging of pollutants; the destruction of plant life; and any other changing of the physical characteristics of land.
>
> *Alter* means to change the condition of any Area Subject to Protection Under the Act. Examples of alterations include, but are not limited to, the following:
>
> (a) the changing of pre-existing drainage characteristics, flushing characteristics, salinity distribution, sedimentation patterns, flow patterns and flood retention areas;
> (b) the lowering of the water level or water table;
> (c) the destruction of vegetation;
> (d) the changing of water temperature, biochemical oxygen demand (BOD), and other physical, biological or chemical characteristics of the receiving water.

The regulations establish inland and coastal resource areas, and establish performance standards which all activity must conform to. There are 11 coastal resource areas and 4 inland resource areas. Those most pertinent to lake and pond projects include

Coastal

Salt Marshes
Land Under Salt Ponds
Banks of or Land Under Ponds, Streams, Rivers, Lakes or Creeks that Underlie an Anadromous/Catadromous Fish Run

Inland

Bank
Bordering Vegetated Wetland
Land Under Waterbodies and Waterways
Land Subject to Flooding

Presumptions of significance (why they are regulated) and performance standards (how to work within them) are established for each.

Application Forms: Request for Determination of Applicability: to identify jurisdiction and regulatory requirements.

Notice of Intent: Full application form for complete project description, analysis of impacts, discussion of mitigating measures.

Permit: Determination of Applicability
Order of Conditions

Further Information:

Contact Regional Office or Local Conservation Commission.

Timing: Public Hearing held within 21 days of filing Notice of Intent. Permit issued/denied within 21 days of close of Public Hearing, and local timing requirements.

Appeal:

- To DEP Regional Office within 10 days of issuance of order or denial.
- To Superior Court if under local ordinance or bylaw.

2. Boards of Health

Jurisdiction: Public Health, Safety and Welfare relative to sewage disposal, bathing beaches.

Authority: MGL Chapter 111

Regulations: Under state law, local Boards of Health, by Board of Health vote, have the authority to adopt local bylaws that regulate disposal of sewage and that regulate bathing beaches.

State Sanitary Code
310 CMR 15.00
105 CMR 445.00

Application Forms: Established locally.

Permit: Established locally.

Timing: Established locally.

Appeal: Superior Court

Further Information: Local Boards of Health Officer.

3. Planning Boards, Boards of Selectmen, Zoning Boards of Appeal

Jurisdiction: Local overlay districts relative to ponds/lakes remediation or management.

Authority: Zoning Enabling Act, MGL Chapter 40A
Subdivision Control Law, MGL Chapter 41, S.81-K - 81-GG

Regulations: Zoning bylaws, ordinances, non-zoning bylaws, ordinances, overlay districts (e.g. watershed, flood plain, wetland, groundwater).

Application Forms: Established locally.

Permit: Established locally.

Timing: Established locally, within bounds of 40A.

Appeal: Established in 40A.

Further Information: Local town officials.

State Permits

The following permits are summarized in Table 4.1 and are described in greater detail in this section.

1. Department of Environmental Protection

   a. Division of Wetlands and Waterways - Wetlands Protection Program

This program has been described fully in the Local Regulation Section, as local Conservation Commissions are responsible for the implementation of the Wetlands Protection Act and the regulations ar 310 CMR 10.00. However, upon appeal, the DEP becomes the issuing authority.

1990 Wetland Program Policy

The DEP is currently in the process of developing a wetlands program policy regarding lake drawdown which will recommend that Conservation Commissions request an applicant to compile a minimum amount of information to assess whether plant species composition will be successfully effected by the drawdown. This information may include the following:

- assess drawdown in relation to the interests in the Act including
- water supply and water quality impacts
- rare species
- refill capacity
- bathymetry of lake
- dam structure
- ground water
- down stream impacts
- wildlife habitat

Mr. Gary Gonyea in the Boston DEP office is preparing the policy.

Appeal Provisions: Upon appeal of a local action, the Request for Determination of Applicability or Notice of Intent and appealed Determination or Order of Conditions are submitted to the Department of Environmental Protection (DEP) for review and issuance of a Superseding Determination of Applicability or Superseding Order of Conditions. Within 10 days of an action by the Conservation Commission, an appeal must be filed with the DEP Regional Office. The Department may issued a Superseding Determination of Applicability within 35 days from receipt of a request and may issue a Superseding Order of Conditions within 70 days of a request (310 CMR 10.05 (3) and (7).

Inter-Agency Requirements: Once an appeal is filed, the issuance of a Superseding Order of Conditions constitutes a state action subject to MEPA. Any project proposing the alteration 5,000 square feet of Bordering Vegetated Wetland, 500 feet or more of Bank or of 1/2 acre of any other wetland resource area must file an ENF (301 CMR 11.26). Any project proposing alteration of one acre of Bordering Vegetated Wetland or 10 acres of wetland resource area or Great Pond is categorically included and must file both an ENF and EIR (301 CMR 11.25).

Further Information:

Regional DEP Office or
Boston Office: Department of
Environmental Protection
Div. of Wetlands and Waterways
One Winter Street
Boston, MA 02018
(617) 292-5695

b. Division of Wetlands and Waterways - Wetlands Restriction Program

Wetlands Restriction Program

Jurisdiction: The purpose of the Wetlands Restriction Program is to map all the state's wetlands and select the most important wetlands for deed restrictions which prohibit activities that would impair their functions. A list of communities having wetlands restrictions is included. Depending on an individual deed restriction, lake management and remediation work may not be allowed. Typically, destruction of natural vegetation, alteration of existing patterns of flow, alteration of natural contours, discharge of pesticides and draining and dredging have been prohibited.

To place a restriction on a wetland area, public hearings and site visits must be held.

Authority:	M.G.L. Chapter 130, section 105, M.G.L. Chapter 131, Section 40A
Regulations:	302 CMR 4.00 and 6.00
Application:	Notice of Intent, per 310 CMR 10.00.
Permit:	Order of Conditions, per 310 CMR 10.00.
Timing:	Same as 310 CMR 10.00.
Appeal:	Same as 310 CMR 10.00.

Inter-Agency Requirements: Orders placed on restricted wetlands within the boundary of the Massachusetts coastal zone will be consistent with the policies and regulations of the Office of Coastal Zone Management (301 CMR 20.00, S. 21.00) or, if the DEP accepts a nomination of a wetland area as an Area of Critical Environmental Concern, it will do so in accordance with procedures for establishment of Areas of Critical Environmental Concern (ACECs), 301 CMR. Additionally, within 15 months of an area being nominated as an ACEC, the program will develop restrictions for the area.

Further Information:
Scott Boots, Program Coordinator
Wetlands Restriction Program
Division of Wetlands & Waterways
One Winter Street
Boston, MA 02108

c. Division of Wetlands and Waterways - Waterways Regulation

Jurisdiction:

(1) all waterways, including all flowed tidelands and all submerged lands lying below the high water mark of:
  (a) Great Ponds;
  (b) the Connecticut River;
  (c) the section of the Westfield River in the Towns of West Springfield and Agawam lying between the confluence of said river with the Connecticut River and the bridge across said river at Suffield Street in said Town of Agawam;
  (d) the non-tidal river or stream on which public funds have been expended for stream clearance, channel improvement, or any form of flood control or prevention work, either upstream or downstream within the river basin, except for any portion of any such river or stream which is not normally navigable during any season, by any vessel including canoe, kayak, raft, or rowboat; the Department may publish, after opportunity for public review and comment, a list of navigable streams and rivers; and
(2) all filled tidelands, except for landlocked tidelands, and all filled lands lying below the natural high water mark of Great Ponds (310 CMR 9.04).

Authority: M.G.L. Chapter 91

Regulations: 310 CMR 9.00

Application Form: Application Form 1; Dredging Addendum Application Form 2; Municipal Zoning Certification Application Form 3; and Municipal Planning Board Notification Application Form 4. To identify whether a project is subject to the regulations, one may submit a Request for Jurisdictional Determination (informal) or a formal Determination of Applicability (310 CMR 9.05). All forms are currently under revision.

Permit: Chapter 91 Permit or Chapter 91 License

Timing: The Department shall issue a license, permit, etc., no later than 90 days after an application is determined to be complete (310 CMR 9.14). The DEP recommends that DEM asks for pre-application consultation per 310 CMR 9.11.

Inter-Agency Requirements: No license or permit will be issued until the MEPA process is complete, a final Order of Conditions is issued, a Water Quality Certification is issued, a Certificate of Compliance with local zoning and copies of all other state regulatory approvals that may apply are submitted. (310 CMR 9.11, 9.33 and 9.34) Additionally, CZM policies and ACEC criteria may need to be complied with, as appropriate.

Appeal: A Notice of Claim for an adjudicatory hearing must be filed within 21 days of the date of issuance of a license or permit. (310 CMR 9.17)

Further Information:
John Simpson (or ask receptionist for the staff person responsible for community in which project is proposed)
Department of Environmental Protection
Division of Wetlands and Waterways
Waterways Regulation Program
One Winter Street
Boston, MA 02108
(617) 292-5695

b. Division of Water Pollution Control - Water Quality Certification

Jurisdiction: Administration of water quality certification of dredged and dredged material disposal and filling. The Water Quality Certification regulations are promulgated in order to establish procedures, criteria and standards for the uniform and coordinated administration of water quality criteria of dredging and dredged material disposal and filling projects in waters of the Commonwealth (314 CMR 9.01).

Authority: Section 27 (12) of the Massachusetts Clean Waters Act, M.G.L. C. 21, sections 26-53.

Regulations: 314 C.M.R. 9.00

Application Form: Two parts: "Standard Application Form" and a "Supplemental Information Form" (314 CMR 9.90).

Permit: Water Quality Certification

Timing: For projects categorically excluded under the MEPA regulations, applicants shall file a Standard Application Form with the Division. For all projects which are not categorically excluded under the MEPA regulations, the applicant shall submit to the MEPA Unit a completed Standard Application Form with the ENF. The Division shall act on a water quality certification within 90 days of the completion of the full application, within 90 days of publication that an EIR is not required or within 90 days of completion of a final EIR. (314 CMR 9.02)

Inter-Agency Requirements: a) Should a project be subject to MEPA regulations, a Standard Application Form must be filed as part of the ENF process. (314 CMR 9.02) b) The regulations are intended to be consistent with and form part of the Coastal Zone Management Program, insofar as a they may apply to a project. c) Section 401 of the the Federal Water Pollution Control Act provides that any applicant for a federal license or permit for a project which may result in a discharge into the navigable waters of a state must provide the Federal licensing agency with a certification from that state's water pollution control agency. d) A water quality certification is required prior to the issuance of a Chapter 91 license.

Appeal: A request for an Adjudicatory Hearing may be filed within 30 days of a Permit Issuance. (314 CMR 2.08)

Further Information: Division of Water Pollution Control
One Winter Street
Boston, MA 02108
(617) 292-5673

c. DEP, Division of Water Pollution Control - License to Apply Chemicals

Jurisdiction: Application of chemicals to water body for weed control

Authority: M.G.L. Chapter 111, Section 5E

Regulations: None

Application Form: Application for License to Apply Chemicals for Control of Nuisance Aquatic Vegetation (copy enclosed)

Permit: License to Apply Chemicals for Control of Nuisance Aquatic Vegetation

Timing: License application must be completed and submitted to the Division of Water Pollution Control, Technical Services Branch at least thirty (30) days prior to the proposed date(s) of treatment.

Inter-Agency Requirements: Licensee shall obtain either a Final Order of Conditions or negative Determination of Applicability prior to application of chemicals. Additionally, chemical application shall only be conducted by an applicator currently licensed by the Massachusetts Department of Food and Agriculture Pesticide Bureau in the aquatic weed category.

Further Information: Division of Water Pollution Control
Technical Services Branch
Lyman School
Westborough, MA 01581
(508) 792-7470

d. DEP, Division of Solid Waste Management

Jurisdiction: Disposal of Dredged Material in approved landfill.

Authority: M.G.L. Chapter 21A, sects. 2 and 8, M.G.L. Chapter 111, Section 150A

Regulations: 310 CMR 19.00

Application Form: If the dredge spoils are not deemed acceptable for sale or use as a daily landfill cover, soil conditioner or embankment fill, Request for Determination whether dredged material or other lake remediation solid waste is a special waste per 310 CMR 19.061.

Permit: Issuance of written determination.

Timing: Not specified

Inter-Agency Requirements: Any work within wetland areas will require compliance with all wetlands related permitting programs.

Further Information: Division of Solid Waste Management
One Winter Street
Boston, MA 02108
(617) 590-5961

2. Department of Fisheries, Wildlife and Environmental Law Enforcement

   a. Division of Fisheries and Wildlife

Jurisdiction: Review of drawdown activities and impact on fisheries and wildlife interests.

Authority: M.G.L. 131 Chapter 42 and 48.

Regulations: None

Application Form: Written Notification to Division, coordination with local Conservation Commission is recommended.

Permit: Conditions recommended by Division to local Conservation Commission

Timing: Notification prior to filing a Notice of Intent under the Wetlands regulations (310 CMR 10.00) is recommended.

Appeal: Under the provision of the Wetlands regulations at 310 CMR 10.00.

Further Information: Division of Fisheries and Wildlife
Westborough, MA
(508) 366-4470

3. Massachusetts Coastal Zone Management

Jurisdiction: Compliance of projects requiring federal permits to coastal zone regulatory and non-regulatory policies in the Massachusetts coastal zone. The regulations are promulgated to comply with the requirements of the Federal Coastal Zone Management Act of 1972, as amended. Any lake remediation or management project which requires a permit from the U.S. Army Corps of Engineers (e.g. filling in wetlands, dredging) or the U. S. Environmental Protection Agency (e.g. NPDES permit), when conducted in the coastal zone will require a CZM consistency review.

Authority: M.G.L. Chapter 21A, Chapter 6A, sections 2-7.

Regulations: 301 CMR 20.00 and 21.00

Application Form: Consistency Certification, federal and state permit applications (as appropriate), final decision of the MEPA process (as appropriate), other information, as deemed necessary. (301 CMR 21.10)

Permit: Concurrence with Consistency Certification, Consistency Certification Determination.

Timing: A CZM Consistency Certification must be issued prior to the issuance of any federal permit. (301 CMR 21.06) When an applicant applies for a federal license or permit and a state license or permit or state funding is also involved, the CZM Office shall automatically find that a coastal zone activity subject to MEPA review can reasonably be expected to affect the coastal zone and is therefore subject to the CZM regulations. Therefore, a CZM Consistency Certification should be filed concurrently with the MEPA process, if appropriate, and prior to filing for a federal permit. In all cases, the CZM Office shall issue its decision within six months of commencement of its final review. In most cases, the CZM Office will not issue a concurrence decision until the EOEA Agency has completed acting on the license or permit application. (301 CMR 21.14)

Inter-Agency Requirements: The CZM Consistency Certification is a requirement prior to the issuance of federal permits for projects in the Massachusetts coastal zone. Additionally, the CZM Office has stated its intention to participate in any MEPA review so as to alert an applicant to any inconsistencies in the proposed activity to the CZM Policies at an early stage.

Further Information: Office of Coastal Zone Management
100 Cambridge Street
Boston, MA 02202
(617)727-9530

4. Massachusetts Historical Commission

Jurisdiction: Elimination, minimization or mitigation of impact to properties listed in the State Register of Historic Places. This may be applicable to lakes management and remediation projects should dredging or drawdown significantly impact an archaeological or historic site. The regulations establish a standardized procedure to protect the public's interest by directing state bodies to notify the Massachusetts Historical Commission as early as possible in the planning process of any project either undertaken by the state body or prior to the state body's funding or licensing a private project.

Authority: M.G.L. Chapter 9, sections 26-27C

Regulations: 950 CMR 71.00

Application Form: Project Notification Form or Environmental Notification Form, depending upon whether MEPA is triggered by the project.

Permit: Determination of Adverse Effect: either No Effect, Determination of No Adverse Effect or Determination of Adverse Effect. (95- CMR 71.07)

Timing: For projects which require review under MEPA and these regulations, project proponents will find it most convenient to follow the procedures established in the regulations at the time the MEPA reports are filed. (950 CMR 71.04) The MHC will issue a written determination of effect within 30 days of receipt of an adequately documented Project Notification Form or Environmental Notification Form. (950 CMR 71.07)

Inter-Agency Requirements: Compliance with MEPA.

Appeal: If the MHC issues a Determination of Adverse Effect, the MHC, the state body and the project proponent shall consult to establish alternatives to the project as proposed that could eliminate, minimize or mitigate adverse effects. Should no agreement be reached the MHC will issue a Memorandum of Agreement outlining MHC's conclusions. The Agreement will be addressed at a meeting of the MHC. Funding or licensing of a project may not proceed until this process is complete. (950 CMR 71.07)

Further Information: Massachusetts Historical Commission
80 Boylston Street
Suite 310
Boston, MA 02116
(617) 727-8470

5. Department of Environmental Management

   a. Office of Dam Safety

Jurisdiction: Safety and inspection of dams greater than 6 feet in height or which can store 15 acre-feet of water or which, upon breach, could endanger property or public safety.

The definition of dam is established at 302 CMR 10.06:

> "Dam shall mean any artificial barrier, including appurtenant works, which impounds or diverts water, and which is (1) twenty-five feet or more in height as defined herein and (2) has an impounding capacity at maximum water storage elevation of fifty acre-feet or more. Dam shall also mean any other artificial barrier, including appurtenant works, the breaching of which could endanger property or safety, as determined by the Commissioner, and is greater than six (6) feet in height or impounds more than fifteen (15) acre feet of water; or any structure classified as a roll dam."

Hazard Potential is defined as "the potential for causing property damage or loss of human life in the event of failure or improper operation of a dam."

Authority: M.G.L. Chapter 253, sections 44-50

Regulations: 302 CMR 10.00

Application Form: Dam Registration Forms, Notice of Intent to determine whether Chapter 253 Permit is required.

Permit: Chapter 253 Permit to Construct, Repair, or Remove a Dam ("Chapter 253 Permit"), Certificate of Compliance or Non-Compliance

Timing: A Chapter 253 Permit will be issued within 30 days from the time the final design report is received and approved.

Inter-Agency Requirements: Work in the vicinity of a dam may require permit filings relative to wetland alteration, e.g. Chapter 91, Wetlands Protection Act.

Further Information:

Office of Dam Safety
Department of Environmental Management
100 Cambridge Street
Boston, MA 02202
(617) 727-3174

6. Massachusetts Environmental Policy Act (MEPA)

Jurisdiction: Overall environmental review of projects requiring state permits, funding or other state action. The Massachusetts Environmental Policy Act regulations provide a uniform system for compliance with the Massachusetts Environmental Policy Act, M.G.L. Chapter 30, sections 61 through 62H. MEPA applies to the activities of all agencies of the Commonwealth, to all activities carried out with financial assistance from agencies, and to all activities which require permits granted by agencies. The regulations establish thresholds, a procedure, and a timetable for a two-level review process, which generally includes filing of an Environmental Notification Form (ENF) and an Environmental Impact Report (EIR).

An ENF and EIR is an informational planning document which is intended to inform project proponents, public decision makers and the general public of the environmental effects of proposed activities, to enable environmental damages and benefits to be fully disclosed and considered. (301 CMR 11.01)

For lake and pond remediation and management work, the MEPA process may be triggered in several ways: if state funds are being used for the proposed activities, if an Order of Conditions is appealed to the Department of Environmental Protection and more than a specified area of wetland resource area is being altered (310 CMR 11.26, filing of an ENF is required) or if more than 10 acres of a wetland resource area is proposed to be altered (301 CMR 11.25, filing of an EIR is required). Additionally, any agency action necessitating physical alteration in an Area of Critical Environmental Concern (ACEC) requires filing of an ENF (301 CMR 11.15).

Authority: M.G.L. Chapter 30, Sections 62 through 62H, inclusive

Regulations: 301 CMR 11.00

Application Form: Environmental Notification Form (ENF), 10 page form with questions asking for project description, description of site environment and regional environment, an analysis of potential impacts and mitigating measures and proposed project benefits. (301 CMR 11.28)

Timing:

1. File ENF on 15th or last day of the month, any time prior to but no later than 10 days after the filing of the first application for a state permit or financial assistance for the project.

2. Secretary publishes the first page of each ENF in the Environmental Monitor generally within 7 to 21 days after receipt. Such publication commences the ENF review period.

    a. A twenty day public comment period falls within this period.
    b. A MEPA public consultation session is held

3. On or before the last day of the ENF review period, the Secretary issues a Certificate establishing either that no EIR is required or establishing the need for and Scope of the EIR.

4. If no EIR is required, state agencies may act. If an EIR is required, prepare and file Draft EIR on 15th or last day of a month.

5. Secretary publishes Notice of Availability of the EIR in the Environmental Monitor within 7 to 21 days of receipt. Such publication commences the 30 day public comment period.

6. Within 7 days of the close of the 30 day public comment period, the Secretary issues a Certificate on the Adequacy of the DEIR.

7. If DEIR is declared adequate, prepare and submit Final EIR on 15th or last day of the month. If the DEIR is declared inadequate, may have to prepare a Supplemental DEIR.

8. Secretary publishes Notice of Availability of the EIR in the Environmental Monitor within 7 to 21 days of receipt. Such publication commences the 30 day public comment period.

9. Within 7 days of close of 30 day public comment period, the Secretary issues a Certificate on the Adequacy of the FEIR.

10. If FEIR is declared adequate, state agencies may act. If FEIR is declared inadequate, may have to prepare Supplemental FEIR. (301 CMR 11.04 - 11.10)

Inter-Agency Requirements: The MEPA process must be completed prior to the issuance of any state permit, release of state funds or initiation of activities by a state agency. (301 CMR 11.10)

If a Division of Water Pollution Control Water Quality Certification is required, the Standard Application Form must be submitted with the ENF. (314 CMR 9.02)

Appeal Provisions: Notice of Intent to Commence an Action filed with the Attorney General, the Secretary and the Proponent. (301 CMR 11.20, 11.29)

Further Information:
Massachusetts Environmental Policy Act Unit
Executive Office of Environmental Affairs
100 Cambridge Street, 20th floor
Boston, MA 02202
(617) 727-5830

A blank ENF is included.

7. Department of Food and Agriculture

a. Pesticide Bureau

Jurisdiction: The purpose of the Pesticide Bureau regulations is to establish the standards, requirements and procedures for the certification and licensing of pesticide applicators, including specific requirements for aquatic pest control. No person shall use a pesticide that has been classified by the

Pesticide Board as being for restricted or state limited use unless he is an appropriately certified private or commercial applicator. (333 CMR 10.03) All certifications and licenses shall be for a period not to exceed one year. Categories of Commercial Applicators are established at 333 CMR 10.04.

Authority: M.G.L. Chapter 132 B, sections 6A and 10

Regulations: 333 CMR 10.00

Application Form: Competence in the use and handling of pesticides shall be determined on the basis of written examinations and performance testing. (333 CMR 10.05) In the case of aquatic pest control, the applicators shall demonstrate practical knowledge of the principals of limited area treatments and the potential for adverse effects on fish, birds, beneficial insects, and other non-target organisms that may be present. (333 CMR 10.05 (2) (e)) Procedures are established at 333 CMR 10.09.

Appeal: Any person aggrieved by a determination of the Board to issue, deny, revoke, modify or suspend any certification may, within 21 days, request an Adjudicatory Hearing before the Board (333 CMR 10.16).

Additional Information:

Pesticide Bureau
Dept. of Food & Agriculture
100 Cambridge Street
Boston, MA 02202
(617) 727-7712

8. Metropolitan District Commission

Jurisdiction: Use of reservoirs, roadways, driveways, bridges, dams, and land within watershed reservations under the care and control of the Metropolitan District Commission are regulated. The regulations establish general regulations relative to use of land within watershed reservations. (350 CMR 8.01) All acts which pollute the water supply are prohibited. No person shall wade or swim unless authorized. Similarly, picnicking, cooking, ball playing, etc. is only allowed where specifically posted or designated. Special regulations for Quabbin Reservoir are established at 350 CMR 8.01 (2) and specify fishing and boating regulations.

Authority: M.G.L. Chapter 92, sections 10-19

Regulations: 350 CMR 8.00

9. Department of Environmental Protection

Jurisdiction: The Department of Environmental Protection has established regulations to promote the public health and general welfare by ensuring that public water systems in Massachusetts provide safe drinking water to its users. The regulations set forth standards and requirements of general application and future effect.

Authority: M.G.L. Chapter 111, section 160A

Regulations: 310 CMR 22.20 addressed surface water supplies and established requirements relative to the use and maintenance of tributary watershed lands. Specific regulations include the following, 310 CMR:

> (2) No cesspool, privy, septic tank, dry well, leaching field, filter or other place for the reception, deposit, or storage of human excrement...shall be located, constructed or maintained within 100 feet of the high water mark of a source of water supply or tributary thereto.
>
> (3) No burial shall be made...except by permission...in any cemetery or other place within 100 feet of the high water mark or a source of public water supply or tributary thereto.
>
> (5) No system of sewers of other works for the collection,...of domestic, municipal, commercial or industrial sewage or drainage...unless...in accordance with the State Environmental Code (310 CMR 11.00 through 18.00) and the State Plumbing Code (248 CMR 1.01 through 2.22).
>
> (7) No person shall wade or bathe in any source of drinking water supply, and no person shall, unless permitted by a written permit,...fish in; enter or go in any boat....

These requirements apply to all land and watercourses used as or tributary to a public water supply system except:

> "(a) Rivers and streams used as sources of supply when the rivers and streams are not impounded at some point by means of a dam or dike to create a reservoir at which the water supply intake is located.

(b) Certain watercourses or bodies of water used as sources of public water supply where conditions are imposed by specific legislation.
(c) Certain watercourses or bodies of water where in the express written opinion of the Department sufficient provisions have been make by means of treatment, storage, restrictions on the time of diversion, or other means to assure an acceptable quality of water.
(d) Emergency sources approved by the Department under the provisions of General Laws, Chapter 40, section 40. "

10. Other State Permits That May Apply For Major Lake Remediation Projects

a. DEP, Division of Water Pollution Control - National Pollutant Discharge Elimination System (NPDES) Permit Program

Jurisdiction: Point Source discharges to surface and ground waters, proper wastewater treatment. This would apply if a treatment plant were proposed in association with lake remediation or management or if a point source discharge of stormwater from certain types of land use were proposed. This permit is issued jointly by the EPA and the Division of Water Pollution Control. A permit is submitted to the EPA and reviewed jointly by both agencies.

Authority: Massachusetts Clean Water Act, M.G.L. Chapter 21, Section 43; Federal Clean Water Act.

Regulations: 314 CMR 2.00, 3.00, 5.00 and 7.00

Application Forms: Application for Permit to Discharge to Waters of the Commonwealth, Application to Discharge to Ground and Application for Permit for Sewer System Extension or Connection.

Permits: Permit for each of the above.

Timing: File at least 180 days prior to discharge (314 CMR 3.09 and 5.09).

Appeal: Within 30 days following issuance of a Permit, a request for an adjudicatory hearing may be filed (314 CMR 2.08).

Inter-Agency Requirements: If subject to MEPA, the MEPA process must be complete.

Further Information:

Division of Water Pollution Control
One Winter Street
Boston, MA 02108
(617) 292-5673

Federal Permits

1. U.S. Army Corps Of Engineers, Section 404 Permit To Dredge And Fill In Waters Of The United States

Jurisdiction: Any activity which results in the dredge and fill in waters of the United States, including wetlands and waterways.

Authority: Rivers and Harbors Act, Clean Waters Act of 1977, Marine Sanctuaries Act.

Regulations: 33 CFR Parts 320-330.

Application Form: Standard Application Form 33 CFR 325, in addition to a Notice of Intent under the Massachusetts Wetlands Protection Act and regulations at 310 CMR 10.00.

Permit: U.S. Army Corps Permit

Timing: Generally, a decision issued no later than 60-90 days after receipt of a completed application (33 CFR 325).

Inter-Agency Requirements: In order for the ACOE to issue a permit, the federal agency must have a Water Quality Certification for the Project. In Order for a Water Quality Certification to have been issued, an Order of Conditions must have been issued for the project, either by the local Conservation Commission or by the Department of Environmental Protection. Additionally, under section 404 (b) (1), the U.S. Environmental Protection Agency has veto authority over the Corps permit process. Full consideration of Fish and Wildlife Service views is required. Additionally, compliance with NEPA, The Endangered Species Act, CZM and National Historic Preservation Act is required.

Appeal: District Court

Additional Information:

Regulatory Branch
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149
(617) 647-8156
(800) 362-4367

2. Environmental Protection Agency - National Pollutant Discharge Elimination System (NPDES) Permit Program

Jurisdiction: Discharge of a point source discharge in waters of the United States. This permit is issued jointly by the EPA and the Division of Water Pollution Control. A permit is submitted to the EPA and reviewed jointly by both agencies.

Authority: Federal Clean Waters Act, section 301 and 402

Regulations: 40 CFR Parts 122-125

Application: NPDES Permit Application

Permit: NPDES Permit

Timing: File application at least 180 days prior to discharge.

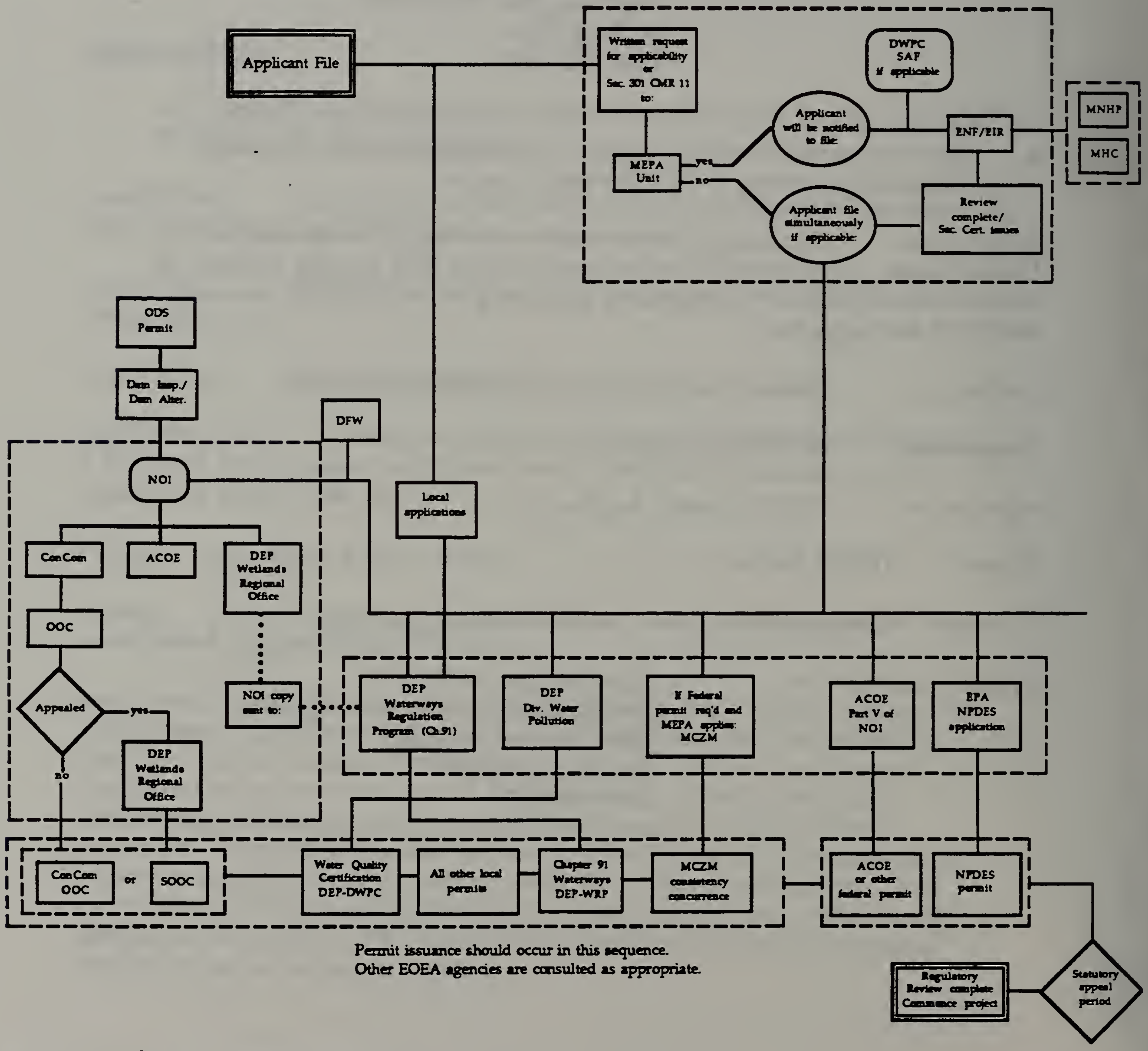
Further Information:

Olga Vergara WCP-2109
Environmental Protection Agency
J.F.K. Federal Building
Boston, MA 02203
(617) 565-3529

FIGURE 4.16

Massachusetts Permit Processing Flow Chart

Flow chart of filing and processing sequence for non-controversial proposed activities relative to lakes management and adjacent wetlands


Applicant File
Written request for applicability or Sec. 301 CMR 11 to:
MEPA Unit
yes
no
Applicant will be notified to file:
Applicant file simultaneously if applicable:
DWPC SAF if applicable
ENF/EIR
Review complete/ Sec. Cert. issues
MNHP
MHC
ODS Permit
Dam Insp./ Dam Alter.
DFW
NOI
Local applications
ConCom
ACOE
DEP Wetlands Regional Office
OOC
Appealed
yes
no
DEP Wetlands Regional Office
NOI copy sent to:
DEP Waterways Regulation Program (Ch.91)
DEP Div. Water Pollution
If Federal permit req'd and MEPA applies: MCZM
ACOE Part V of NOI
EPA NPDES application
ConCom OOC
or
SOOC
Water Quality Certification DEP-DWPC
All other local permits
Chapter 91 Waterways DEP-WRP
MCZM consistency concurrence
ACOE or other federal permit
NPDES permit
Regulatory Review complete Commence project
Statutory appeal period

Permit issuance should occur in this sequence.
Other EOEA agencies are consulted as appropriate.

Adapted from Massachusetts Coastal Permit Processing Flow Chart, Technical Bulletin No. 4, June 1989, Coastal Brief, Jim O'Connell, Author.

Key to Acronyms on following page

FIGURE 4.16 (continued)

Massachusetts Permit Processing Flow Chart

Key to Acronyms

ACOE	U.S. Army Corps of Engineers
ConCom	Conservation Commission
CZM	Massachusetts Coastal Zone Management Office
DEP	Department of Environmental Protection
DFW	Division of Fisheries and Wildlife
DWPC	DEP - Division of Water Pollution Control
EIR	Environmental Impact Report
ENF	Environmental Notification Form
EOEA	Executive Office of Environmental Affairs
EPA	Environmental Protection Agency
LAC	License to Apply Chemicals
MEPA	Massachusetts Environmental Policy Act
MHC	Massachusetts Historical Program
MHWL	Mean High Water Line
MNHP	Massachusetts Natural Heritage Program
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
ODS	DEM - Office of Dam Safety
OOC	Order of Conditions
SAF	Standard Application Form for the DEP - DWPC
Sec. Cert.	Certificate of the Secretary of Environmental Affairs regarding completion of MEPA process
SOOC	Superceding Order of Conditions
WPA	Wetlands Protection Act
WRP	DEP - Waterways Regulation Program

SOURCES OF FURTHER INFORMATION

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Metropolitan Area Planning Council. 1978. Lake management. *In* Water resources protection techniques. pp. 58-63.

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Tourbier, J. Toby and Richard Westmacott. 1981. Water resources protection technology: a handbook of measures to protect water resources in land development. The Urban Land Institute, Washington, D.C.

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Wetzel, Robert G., Limnology, W.B. Saunders Company, 1975.

Wisconsin Department of Natural Resources, Environmental Assessment Aquatic Plant Management, (NR107) Program, (2nd Edition), February, 1989.

SOURCES OF FURTHER INFORMATION
(continued)

List of Regulatory Agencies and Permit Application Forms

Regulatory Agencies

The regional DEQE offices are:

DEQE Northeast Regional Office
5 Commonwealth Avenue
Woburn, MA 01801
(508)935-2160

DEQE Southeastern Regional Office
Lakeville Hospital
Lakeville, MA 02346
(508)947-1231

DEQE Central Regional Office
75 Grove Street
Worcester, MA 01605
(508)792-7650

DEQE Western Regional Office
State House West-4th Floor
436 Dwight Street
Springfield, MA 01103
(413)785-5327

District Office of the Division of Fisheries and Wildlife are as follows:

FIELD HEADQUARTERS:
Division of Fisheries and Wildlife
Field Headquarters
Westborough, MA 01581
(508)366-9181

WESTERN:
Wildlife District Manager
Hubbard Avenue
Pittsfield, MA 01201
(413)447-9789

CENTRAL:
Wildlife District Manager
Temple Street
W. Boylston, MA 01583
(617)835-3607

SOUTHEAST:
Wildlife District Manager
Bournedale Road
Buzzards Bay, MA 02532
(617)759-3406

CONNECTICUT VALLEY:
Wildlife District Manager
East Street
Belchertown, MA 01007
(413)323-7632

NORTHEAST:
Wildlife District Manager
Harris Street, Box 86
Acton, MA 01720
(617)263-4347

PERMIT APPLICATION FORMS

As of January,1990 the following Cities and Towns have Orders of Restriction under either the "Coastal Wetlands Restriction Act" Chapter 130,Section 105, or the "Inland Wetlands Restriction Act" Chapter 131,Section 40A.

Coastal Wetlands Restriction Act

1) Quincy.........6.20.66
2) Pembroke......12.27.66
3) Ipswich.........4.4.68
4) Norwell.........7.1.69
5) Hanover.........7.1.69
6) Newburyport....10.1.69
7) Westport.......1.29.70
8) Essex..........5.15.70
9) Rowley.........6.16.70
10) Wareham........1.12.71
11) Salisbury......3.15.71
12) Newbury........3.15.71
13) Marshfield.....4.11.71
14) Marion.........4.11.72
15) Duxbury........4.11.72
16) West Tisbury...7.24.74
17) Tisbury........7.24.74
18) Oak Bluffs.....7.24.74
19) Gay Head.......7.24.74
20) Chilmark.......8.14.74
21) Cohasset.......12.3.74
22) Eastham........6.30.75
23) Edgartown......9.29.75
24) Truro..........3.18.76
25) Orleans.......11.30.76
26) Sandwich.......3.10.80
27) Bourne..........8.6.80
28) Brewster......11.13.80
29) Harwich.......11.13.80
30) Gloucester....11.14.80
31) Yarmouth.......2.17.81
32) Falmouth....... 6.3.81
33) Barnstable......9.8.81
34) Dennis........12.10.81
35) Plymouth......12.10.81
36) Provincetown...1.13.82
37) Wellfleet......5.20.82
38) Nantucket......8.10.82
39) Chatham.........8.4.82
40) Weymouth.......3.26.87
41) Hingham........3.26.87
42) Mashpee........7.13.87

Inland Wetlands Restriction Act

1) Wellesley.........11.10.71
2) Dover..............6.26.72
3) Dedham............12.19.74
4) Westwood...........4.24.74
5) Needham............9.13.75
6) Walpole.............1.5.76
7) Waltham............3.30.76
8) Newton.............4.22.77
9) Millis.............11.4.77
10) Norfolk............3.31.78
11) Marlborough........4.20.78

Both Inland/Coastal

1) Eastham............6.30.75
2) Truro..............3.18.76
3) Orleans...........11.30.76
4) Sandwich...........3.10.80
5) Provincetown.......1.13.82
6) Hingham............3.26.87

310 CMR 10.99

Form 1

DEP File No ______

(To be provided by DEP)

City/Town ______

Applicant: ______

Commonwealth
of Massachusetts

Request for a Determination of Applicability
Massachusetts Wetlands Protection Act, G.L. c. 131, §40

1. I, the undersigned, hereby request that the ______ Conservation Commission make a determination as to whether the area, described below, or work to be performed on said area, also described below, is subject to the jurisdiction of the Wetlands Protection Act, G.L. c. 131, §40.

2. The area is described as follows. (Use maps or plans, if necessary, to provide a description and the location of the area subject to this request.)

   Location: Street Address ______

   Lot Number: ______

3. The work in said area is described below. (Use additional paper, if necessary, to describe the proposed work.)

4. The owner(s) of the area, if not the person making this request, has been given written notification of this request on ______________________________(date)
The name(s) and address(es) of the owner(s):

5. I have filed a complete copy of this request with the appropriate regional office of the Massachusetts Department of Environmental Protection ______________________________(date)

DEP Northeast Regional Office
5 Commonwealth Avenue
Woburn, MA 01801

DEP Central Regional Office
75 Grove Street
Worcester, MA 01605

DEP Southeast Regional Office
Lakeville Hospital
Route 105
Lakeville, MA 02347

DEP Western Regional Office
State House West, 4th Floor
436 Dwight Street
Springfield, MA 01103

6. I understand that notification of this request will be placed in a local newspaper at my expense in accordance with Section 10.05(3) (b) 1 of the regulations by the Conservation Commission and that I will be billed accordingly.

Signature ______________________ Name ______________________________

Address ______________________________________ Tel.______________

Commonwealth
of Massachusetts

General Instructions
for Completing
Notice of Intent (Form 3)
and
Abbreviated Notice of Intent (Form 4)
Massachusetts Wetlands Protection Act
G.L. c. 131, §40

and for application to the U.S. Army Corps of Engineers for a Department of the Army permit and to the Massachusetts DEP Division of Waterways for a Chapter 91 license.

Purpose

The purpose of the Notice of Intent is to provide the Conservation Commission and the Department of Environmental Protection (the "Department") with a complete and accurate description of the following:

- The site, including the type and boundaries of areas subject to protection ("resource areas") and,
- The proposed work, including all measures and designs proposed to meet the performance standards set forth under each applicable resource area specified in Part II and Part III of the regulations.

This information is necessary for the issuing authority (i.e., the Conservation Commission or the Department) to fulfill its responsibility to protect the Commonwealth's wetlands resources in accordance with the Wetlands Protection Act, G.L. c. 131, §40 (the "Act").

Responsibility of Applicant

The role of the issuing authority is that of a reviewing agency. It is the applicant's responsibility to provide all of the information required for this review. It is therefore in your interest to submit as complete and accurate a description of your project as possible to ensure that requests for additional information by the Conservation Commission or the Department do not result in an unnecessary delay of your project.

Abbreviated Notice of Intent

The Abbreviated Notice of Intent (Form 4) is provided to simplify filing requirements for projects which are likely to result in limited impacts on resource areas. This form may be used when:

1. the proposed work is within the Buffer Zone (if the filing of a Notice of Intent is required) or is within Land Subject to Flooding, as defined in Part III, Section 10.57 (2) of the DEP regulations; and,
2. the proposed work will alter less than 1000 square feet of surface area within the Buffer Zone or Land Subject to Flooding; and
3. neither a Department of the Army permit nor a Division of Waterways license is required.

Submittal Requirements

Before a Conservation Commission can go forward with its review, the applicant must submit the following materials:

1. To the Conservation Commission:

(a) Two (2) copies of a completed Notice of Intent (Form 3 of Section 10.99) or Abbreviated Notice of Intent (Form 4 of Section 10.99), whichever is applicable.

(b) Two (2) copies of plans, supporting calculations and other documentation necessary to completely describe the proposed work and mitigating measures.

(c) Two (2) copies of plans showing compliance with Title 5 of the State Environmental Code, 310 CMR 15.00, if applicable (i.e., whenever a subsurface sewage disposal system is involved: see Part I, Section 10.03(3) of the regulations).

(d) Two copies of an 8½" X 11" section of the USGS quadrangle map of the area, containing sufficient information for the Conservation Commission and the Department to locate the site of the work.

(e) The filing fee, as determined in 801 CMR 4.02 (310), 50 percent of the fee in excess of $25 made payable to the Commonwealth of Massachusetts and sent to the DEP lock box, and the remainder of the fee made payable to the City or Town where the land on which the work to be done is located (310 CMR 10.07(a)).

(f) If applicable, two copies of a completed Appendix A and required supporting materials, along with evidence that they were received by the Massachusetts Natural Heritage and Endangered Species Program prior to filing a completed Notice of Intent, (i.e., whenever the proposed work would alter a resource area which is located on an Estimated Habitat Map of rare species occurrences; see "Protection of Rare Species Habitat", p.GI-4, below, and Sections 10.37 and 10.59 of the regulations).

2. To the DEP regional office: Two (2) copies of the materials indicated above in items (a)-(d), and (f).

3. If applicable, to the Massachusetts Natural Heritage and Endangered Species Program: One (1) copy of a completed Appendix A, 90 days or less prior to the filing of a Notice of Intent or Abbreviated Notice of Intent; in addition, upon filing of a Notice of Intent or Abbreviated Notice of Intent (in cases where Appendix A is required), one (1) copy of the materials indicated in items (a)-(d), and (f).

Plans

Plans should be of adequate size, scale and detail to completely and accurately describe the site and the work proposed. The following guidelines are provided to encourage uniformity:

Sheet Sizes:

- Maximum 24" X 36".
- Where more than one sheet is required to describe the proposed work, provide an additional sheet indexing all other sheets and showing a generalized composite of all work proposed within the Buffer Zone and Areas Subject to Protection Under the Act.

Scale:

- Not more than 1" = 50'.
- Where plans are reduced, display graphical scales.

Margins:

- For 8½" X 11" plans, at least 1" left margin for binding, and all other margins at least ½".
- For plans larger than 8½" X 11", at least a 2" left margin for binding and all other margins at least ½".

Title Block:

- Included on all plans.
- Located at the lower right-hand corner, oriented to be read from the bottom when bound at the left margin.
- Include original date plus provisions for dates and nature of revisions.

Requirement for Professional Services

The issuing authority may require that supporting plans and calculations be prepared and stamped by a registered professional engineer (PE) when, in its judgment, the complexity of the proposed work warrants this professional certification.

The following are examples of the type of information most likely to require certification by a PE:

- hydraulic and hydrologic calculations
- critical elevations and inverts
- drawings for water control structures such as head walls, dams, and retention areas.

The issuing authority may also require that supporting materials be prepared by other professionals including, but not limited to, a registered architect, registered landscape architect, registered land surveyor, registered sanitarian, biologist, ecological scientist, geologist or hydrologist when in its judgement the complexity of the proposed work warrants the relevant specialized expertise.

Permits, Variances and Approvals

Permits, variances and approvals required by local by-law may include, among others, zoning variances, permits from boards of appeals, permits required under floodplain or wetland zoning by-laws and gravel removal permits; they do not include, among others, building permits under the State Building Code, G.L. c. 23 B, §16, or subdivision control approvals under the State Subdivision Control Law, G.L. c. 41, §§81K-81-GG, which are issued by local authorities.

Areas Subject to Wetlands Restrictions

To determine if an area is subject to a Wetlands Restriction Order pursuant to G.L. c. 131, §40A or G.L. c. 130, §105 contact the Conservation Commission for the town in which your project is located, the Department office in your region, or:

Division of Wetlands and Waterways Regulation
Department of Environmental Protection
One Winter Street
Boston, Massachusetts 02108

Boundaries of Resource Areas

The boundary of the Buffer Zone is determined by measuring 100 feet horizontally from those areas specified in Section 10.02(1) (a) of the regulations.

The boundaries of coastal Areas Subject to Protection Under the Act can be determined by reference to the definitions provided under each coastal resource area in Part II of the regulations and by reference to the publication entitled *A Guide to the Coastal Wetlands Regulations.* *

The boundaries of inland Areas Subject to Protection Under the Act can be determined by reference to subsection (2), "Definitions, Critical Characteristics and Boundaries", for each resource area in Part III of the regulations.

***This publication is available for $4.00/copy. Make check payable to Massachusetts Cooperative Extension Service and send to Bulletin Center, Cottage A, Thatcher Way, University of Massachusetts, Amherst, MA 01003.**

Protection of Rare Species Habitat

No work subject to the Act may be permitted to have any adverse effects on the habitat of local populations of rare, "state-listed" vertebrate or invertebrate animal species located within any resource area. In determining whether proposed work will have any such adverse effect, an applicant must, 90 days or less prior to filing a Notice of Intent, contact the conservation commission to see if the proposed work is located within an area described on the most recent Estimated Habitat Map (if any) of "occurrences" of state-listed species provided to the conservation commission by the Natural Heritage and Endangered Species Program (the "Program"). If the proposed work is located within such an area, the applicant shall inform the Program by certified mail or hand delivery, so that the Program shall have received such notification 90 days or less prior to the filing of a Notice of Intent. Such notification shall consist of a completed copy of Appendix A of the Notice of Intent (Form 3) or Abbreviated Notice of Intent (Form 4), as well as a copy of an 8 ½" x 11" section of the USGS quadrangle map of the area, containing sufficient information for the Program to locate the precise boundaries of the portion(s) of wetland resource area(s) to be altered. The Natural Heritage and Endangered Species Program is located in the Division of Fisheries and Wildlife, 100 Cambridge Street, Boston, MA 02202; telephone 617/727-9194, -3151.

Coordinated Processing with the U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (COE) has the following regulatory authority over certain areas that are also subject to protection under the Wetlands Protection Act:

Section 404 of the Clean Water Act For the placement of fill or discharge of dredged material within wetlands, below the ordinary high water line in inland areas and below the high tide line in coastal areas.

Section 10 of the River and Harbor Act of 1899 For any work below the ordinary high water line in the Connecticut and non-tidal portions of the Merrimack Rivers in inland areas, and below the mean high water line in coastal areas.

Failure to obtain the required authorization is a violation of these Federal laws, and as such is subject to criminal and civil prosecution by the U.S. Attorney that could result in having to remove the illegal fill and pay a fine.

To reduce delays, the Notice of Intent is designed to serve, at the applicant's option, as an application form for a Department of the Army permit. Simultaneous processing may be initiated by the applicant in the following manner:

1. Determine if the proposed work is in a resource area(s) likely to involve COE jurisdiction by completing Part I, item 11 of the Notice of Intent (Form 3).
2. When concurrent jurisdiction appears likely, submit a copy of the Notice of Intent with Parts I-IV completed and supporting materials to COE, at the same time it is filed with the Conservation Commission.
3. COE will notify the applicant within 15 days of receipt of the Notice of Intent and supporting materials as to whether a Department of the Army permit is required.
4. When COE determines that a Department of the Army permit is required, the information required in Part V of the Notice of Intent must be furnished. By furnishing this information with the original submission to COE, the time required to issue a Department of the Army permit may be greatly reduced.

For additional information concerning the Department of the Army permit programs write COE or call it collect at the following address or number:

U.S. Department of the Army Corps of Engineers
New England Division Regulatory Branch
424 Trapelo Road, Waltham, Massachusetts 02254
1-800-362-4367 (toll-free)

DEP Division of Waterways Chapter 91 License Requirements

The DEP Division of Waterways ("Waterways") also has regulatory authority within certain areas subject to the Wetlands Protection Act. Generally, in accordance with Chapter 91 of the Massachusetts General Laws, a Waterways License is required for work below the high water mark in coastal areas, in inland great ponds and rivers, and in streams for which public funds have previously been spent.

The Department will notify the applicant as to whether a Chapter 91 license is required within 21 days of receipt by the regional office of the completed Notice of Intent and supporting documents. When a license is required, the following is a general list of the additional documents and information that must be provided by the applicant:

1. A completed Waterways application (if the Department determines that a Chapter 91 license is required, a blank application form and instructions will be sent to the applicant along with the determination).
2. A 10" x 16" plan prepared according to Waterways specifications and the rules and regulations of the Registry of Deeds.
3. A copy of the final order issued under the Wetlands Protection Act.

If you have any questions concerning the Notice of Intent, please contact the Conservation Commission for the town in which your project is located or the Department office in your region:

DEP Northeast Regional Office
5 Commonwealth Avenue
Woburn, MA 01801 617-935-2160

DEP Central Regional Office
75 Grove Street
Worcester, MA 01605 508-792-7650

DEP Southeast Regional Office
Lakeville Hospital
Route 105
Lakeville, MA 02347 508-946-2800

DEP Western Regional Office
State House West, 4th Floor
436 Dwight Street
Springfield, MA 01103 413-784-1100

310 CMR 10.99

Form 3

Commonwealth
of Massachusetts

DEP File No. ____________

(To be provided by DEP)

City/Town ____________

Applicant ____________

Notice of Intent
Under the
Massachusetts Wetlands Protection Act, G.L. c. 131, §40
and
Application for a Department of the Army Permit

Part I: General Information

1. Location: Street Address ____________
   Lot Number ____________

2. Project: Type ____________ Description ____________

3. Registry: County ____________ Current Book ____________ & Page ____________
   Certificate (If Registered Land) ____________

4. Applicant ____________ Tel. ____________
   Address ____________

5. Property Owner ____________ Tel. ____________
   Address ____________

6. Representative ____________ Tel. ____________
   Address ____________

7. a. Have the Conservation Commission and the Department's Regional Office each been sent, by certified mail or hand delivery, 2 copies of completed Notice of Intent, with supporting plans and documents?
   Yes ☐ No ☐
   b. Has the fee been submitted? ☐ Yes ☐ No
   c. Total Filing Fee Submitted ____________
   d. City/Town Share of Filing Fee ____________ State Share of Filing Fee ____________
   (sent to City/Town) (½ of fee in excess of $25, sent to DEP)
   e. Is a brief statement attached indicating how the applicant calculated the fee? ☐ Yes ☐ No

8. Have all obtainable permits, variances and approvals required by local by-law been obtained?
Yes ☐ No ☐

Obtained:	Applied For:	Not Applied For:

9. Is any portion of the site subject to a Wetlands Restriction Order pursuant to G.L. c. 131, §40A or G.L. c. 130, §105? Yes ☐ No ☐

10. List all plans and supporting documents submitted with this Notice of Intent.

Identifying Number/Letter	Title, Date

11. Check those resource areas within which work is proposed:

(a) ☐ Buffer Zone

(b) Inland:

☐ Bank*
☐ Bordering Vegetated Wetland*
☐ Land Under Water Body & Waterway*

Land Subject to Flooding,
☐ Bordering
☐ Isolated

(c) Coastal:

☐ Land Under the Ocean*
☐ Coastal Beach*
☐ Barrier Beach
☐ Rocky Intertidal Shore*
☐ Land Under Salt Pond*
☐ Fish Run*

☐ Designated Port Area*
☐ Coastal Dune
☐ Coastal Bank
☐ Salt Marsh*
☐ Land Containing Shellfish*

*Likely to involve U.S. Army Corps of Engineers concurrent jurisdiction. See General Instructions for Completing Notice of Intent.

12. Is the wetland resource area to be altered by the proposed work located on the most recent Estimated Habitat Map (if any) of rare, "state-listed" vertebrate and invertebrate animal species occurrences provided to the conservation commission by the Natural Heritage and Endangered Species Program?

YES [ ]　　NO [ ]　　Date printed on the Estimated Habitat Map issued
NO MAP AVAILABLE [ ]　　(if any) ______________________

If yes, have you completed an Appendix A and a Notice of Intent and filed them, along with supporting documentation with the Natural Heritage and Endangered Species Program by certified mail or hand delivery, so that the Program shall have received Appendix A prior to the filing of this Notice of Intent?

YES [ ]　　NO [ ]

Part II: Site Description

Indicate which of the following information has been provided (on a plan, in narrative description or calculations) to clearly, completely and accurately describe existing site conditions.

Identifying
Number/Letter
(of plan, narrative
or calculations)

Natural Features:

______________ Soils
______________ Vegetation
______________ Topography
______________ Open water bodies (including ponds and lakes)
______________ Flowing water bodies (including streams and rivers)
______________ Public and private surface water and ground water supplies on or within 100 feet of site
______________ Maximum annual ground water elevations with dates and location of test
______________ Boundaries of resource areas checked under Part I, item 11 above
______________ Other

Man-made Features:

______________ Structures (such as buildings, piers, towers and headwalls)
______________ Drainage and flood control facilities at the site and immediately off the site, including culverts and open channels (with inverts), dams and dikes
______________ Subsurface sewage disposal systems
______________ Underground utilities
______________ Roadways and parking areas
______________ Property boundaries, easements and rights-of-way
______________ Other

Part III: Work Description

Indicate which of the following information has been provided (on a plan, in narrative description or calculations) to clearly, completely and accurately describe work proposed within each of the resource areas checked in Part I, item 11 above.

Identifying
Number/Letter
(of plan, narrative
or calculations)

Planview and Cross Section of:

______________ Structures (such as buildings, piers, towers and headwalls)
______________ Drainage and flood control facilities, including culverts and open channels (with inverts), dams and dikes
______________ Subsurface sewage disposal systems & underground utilities
______________ Filling, dredging and excavating, indicating volume and composition of material
______________ Compensatory storage areas, where required in accordance with Part III, Section 10:57 (4) of the regulations
______________ Wildlife habitat restoration or replication areas
______________ Other

Point Source Discharge

______________ Description of characteristics of discharge from point source (both closed and open channel), when point of discharge falls within resource area checked under Part I, item 11 above, as supported by standard engineering calculations, data and plans, including but not limited to the following:

1. Delineation of the drainage area contributing to the point of discharge:
2. Pre- and post-development peak run-off from the drainage area, at the point of discharge, for at least the 10-year and 100-year frequency storm:
3. Pre- and post-development rate of infiltration contributing to the resource area checked under Part I, item 11 above:
4. Estimated water quality characteristics of pre- and post-development run-off at the point of discharge.

Part IV: Mitigating Measures

1. Clearly, completely and accurately describe, with reference to supporting plans and calculations where necessary:
    - (a) All measures and designs proposed to meet the performance standards set forth under each resource area specified in Part II or Part III of the regulations; or
    - (b) why the presumptions set forth under each resource area specified in Part II or Part III of the regulations do not apply.

☐ Coastal ☐ Inland Resource Area Type:	Identifying number or letter of support documents

☐ Coastal ☐ Inland Resource Area Type:	Identifying number or letter of support documents

☐ Coastal ☐ Inland	Resource Area Type.	Identifying number or letter of support documents

2. Clearly, completely and accurately describe, with reference to supporting plans and calculations where necessary:

   (a) all measures and designs to regulate work within the Buffer Zone so as to ensure that said work does not alter an area specified in Part I, Section 10.02(1) (a) of these regulations; or

   (b) if work in the Buffer Zone will alter such an area, all measures and designs proposed to meet the performance standards established for the adjacent resource area specified in Part II or Part III of these regulations.

☐ Coastal ☐ Inland	Resource Area Type Bordered By 100-Foot Discretionary Zone:	Identifying number or letter of support documents

Part V: Additional Information for a Department of the Army Permit

1. COE Application No. ____________________ 2. ________________________________
(to be provided by COE) (Name of waterway)

3. Names and addresses of property owners adjoining your property:

4. Document other project alternatives (i.e., other locations and/or construction methods, particularly those that would eliminate the discharge of dredged or fill material into waters or wetlands).

5. 8½" x 11" drawings in planview and cross-section, showing the resource area and the proposed activity within the resource area. Drawings must be to scale and should be clear enough for photocopying.

Certification is required from the Division of Water Pollution Control before the Federal permit can be issued. Certification may be obtained by contacting the Division of Water Pollution Control, 1 Winter Street, Boston, Massachusetts 02108.

Where the activity will take place within the area under the Massachusetts approved Coastal Zone Management Program, the applicant certifies that his proposed activity complies with and will be conducted in a manner that is consistent with the approved program.

Information provided will be used in evaluating the application for a permit and is made a matter of public record through issuance of a public notice. Disclosure of this information is voluntary, however, if necessary information is not provided, the application cannot be processed nor can a permit be issued.

I hereby certify under the pains and penalties of perjury that the foregoing Notice of Intent and accompanying plans, documents and supporting data are true and complete, to the best of my knowledge.

____ ____________________
Signature of Applicant Date

____ ____________________
Signature of Applicant's Representative Date

NED FORM 100 (TEST)
1 MAY 82

"Exception to ENG Form 4345 approved by HQUSACE, 6 May 1982"

"This document contains a joint Department of the Army and State of Massachusetts application for a permit to obtain permission to perform activities in United States waters. The Office of Management and Budget (OMB) has approved those questions required by the US Army Corps of Engineers. OMB Number 0702-0036 and expiration date of 30 September 1983 applies" This statement will be set in 6 point type.

10.99: continued

Form 4

DEQE File No. ☐
(To be provided by DEQE)

City/Town ______________

Applicant ______________

Commonwealth
of Massachusetts

Abbreviated Notice of Intent
Massachusetts Wetlands Protection Act, G.L. c. 131, §40

To be used only for projects of minimum impact, as described in the General Instructions for Completing the Notice of Intent.

1. Location: Street Address ______________ Lot Number ______________

2. Project: Type ______________ Description ______________

____

____

3. Registry: County ______________ Current Book ______________ & Page ______________

Certificate (If Registered Land) ______________

4. Applicant: ______________ Tel. ______________

Address: ______________

5. Property Owner: ______________ Tel. ______________

Address: ______________

6. Representative: ______________ Tel. ______________

Address ______________

7. Have the Conservation Commission and DEQE Regional Office each been sent, by certified mail or hand delivery, 2 copies of completed Notice of Intent, with supporting plans and documents?

Yes ☐ No ☐

8. Have all obtainable permits, variances and approvals required by local by-law been obtained or applied for? Yes ☐ No ☐

Obtained:	Applied For:	Not Applied For:

9. Is any portion of the site subject to a Wetlands Restriction Order pursuant to G.L. c. 131, §40A or G.L. c. 130, §105? Yes ☐ No ☐

10. List all plans and supporting documents submitted with this Notice of Intent.

Identifying Number/Letter	Title/Date

10.99: continued

11. For work proposed within the Buffer Zone (as defined in Part I, Sections 10.02(2) and 10.04 of the regulations) describe, with reference to supporting plans and calculations where necessary:

(a) The size, shape, type and location of the proposed work.

(b) Mitigating measures and designs to insure that the proposed work will not alter the resource area which said Buffer Zone borders; or if it will alter said resource area, the mitigating measures and designs proposed to meet the performance standard established for that resource area in Part II or Part III of these regulations.

12. For work proposed within Land Subject to Flooding (as defined in Part III, Section 10.57(2) of the regulations) describe, with reference to supporting plans and calculations where necessary:

(a) The size, shape, type and location of the proposed work.

(b) Mitigating measures and designs proposed to meet the performance standards set forth in Part III, Sections 10.57(4) and 10.60 of the regulations.

13. For proposed work within Land Subject to Flooding which will alter said resource area, or for proposed work in a Buffer Zone which will alter the resource area which said Buffer Zone borders, is the area which will be altered located on the most recent Estimated Habitat Map (if any) of rare, "state-listed" vertebrate and invertebrate animal species occurrences provided to the conservation commission by the Natural Heritage and Endangered Species Program?

YES [ ] NO [ ] Date printed on the Estimated Habitat Map issued
NO MAP AVAILABLE [ ] (if any) ______________________________

If yes, have you completed an Appendix A and a Notice of Intent and filed them, along with supporting documentation with the Natural Heritage and Endangered Species Program in person, or by courier or registered mail, so that the Program shall have received Appendix A prior to the filing of this Notice of Intent?

YES [ ] NO [ ]

10.99: continued

I hereby certify under the pains and penalties of perjury that the foregoing Notice of Intent and accompanying plans, documents and supporting data are true and complete, to the best of my knowledge.

Signature of Applicant	Date
Signature of Applicant's Representative	Date

Chapter 91 Waterways License Application

TO WHOM IT MAY CONCERN

All application materials and correspondence should be forwarded to the following address:

Department of Environmental Protection
Division of Wetlands and Waterways
Waterways Regulation Program
One Winter Street - Eighth Floor
Boston, MA 02108

Be sure to include a copy of your Order of Conditions or your Notice of Intent (if an Order of Conditions has not yet been received) with this application.

Thank-you,

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WETLANDS AND WATERWAYS REGULATION
CHAPTER 91 WATERWAYS REGULATION PROGRAM

APPLICATION FORM 1

WATERWAYS FILE NUMBER ____________ DATE RECEIVED (DEP USE ONLY) ____________

NAME OF APPLICANT ____________

ADDRESS ____________ MUNICIPALITY ____________

STATE ____________ ZIP CODE ______ COUNTY ____________

PROJECT DESCRIPTION ____________

____

____

PROPOSED USE: WATER DEPENDENT ________ NON-WATER DEPENDENT ________

DESCRIPTION OF USE ____________

____

BODY OF WATER ____________

[ ] TIDAL WATERS [ ] RIVER/STREAM [ ] GREAT POND [ ]FILLED TIDELDS
(please check one or more of the above)

PROPERTY OWNER ____________ PROPERTY ADDRESS ____________

MUNICIPALITY ____________ COUNTY ____________

APPLICANT'S REPRESENTATIVE ____________

ADDRESS ____________ MUNICIPALITY ____________

STATE ____________ ZIP CODE ________ TELEPHONE ____________

I HEREBY CERTIFY UNDER THE PAINS AND PENALTIES OF PERJURY THAT ALL INFORMATION PROVIDED IN THIS APPLICATION AND ITS PLANS IS TRUE AND ACCURATE.

SIGNATURE OF APPLICANT ____________ DATE ____________

SIGNATURE OF REPRESENTATIVE ____________ DATE ____________

PLEASE TYPE OR PRINT ALL INFORMATION

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WETLANDS AND WATERWAYS REGULATION
WATERWAYS REGULATION PROGRAM

WATERWAYS LICENSE APPLICATION
DREDGING ADDENDUM
APPLICATION FORM 2

____
WATERWAYS FILE NO.

DESCRIPTION OF DREDGING PROJECT ______________________________

____

____

____

PURPOSE OF DREDGING ______________________________

____

VOLUME OF MATERIAL TO BE DREDGED ______________________________

METHOD OF DREDGING ______________________________

DISPOSAL METHOD AND SPECIFIC LOCATION ______________________________

____

____

(PLEASE INCLUDE SEPARATE DISPOSAL SITE LOCATION MAP)

NAME OF APPLICANT ______________________________

SIGNATURE OF APPLICANT ______________________________

DATE ______________________________

PLEASE TYPE OR CLEARLY PRINT ALL INFORMATION

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WETLANDS AND WATERWAYS REGULATION
WATERWAYS REGULATION PROGRAM

MUNICIPAL ZONING CERTIFICATION
APPLICATION FORM 3

____
WATERWAYS FILE NO.

NAME OF APPLICANT ____

PROJECT STREET ADDRESS ____

CITY/TOWN ____

WATERWAY ____

DESCRIPTION OF PROPOSED USE OR CHANGE IN USE _________________________

____

____

(to be completed by Municipal Clerk or Appropriate Municipal Official)

I HEREBY CERTIFY THAT THE PROJECT DESCRIBED ABOVE AND MORE FULLY DETAILED IN THE APPLICANT'S WATERWAYS LICENSE APPLICATION AND PLANS IS NOT IN VIOLATION OF LOCAL ZONING ORDINANCES AND BYLAWS.

SIGNATURE OF MUNICIPAL OFFICIAL ______________________________________

TITLE ____

CITY/TOWN OF ____

DATE ____

PLEASE TYPE OR CLEARLY PRINT ALL INFORMATION

NOTICE TO APPLICANT:
THIS FORM MUST BE SUBMITTED ALONG WITH THE ORIGINAL APPLICATION MATERIALS. IF THE FORM CANNOT BE EXECUTED BY THE APPROPRIATE MUNICIPAL OFFICIAL AT THE TIME OF DELIVERY, THE APPLICANT SHOULD WAIT UNTIL HE RECEIVES THE EXECUTED FORM BEFORE SUBMITTING THE COMPLETED APPLICATION PACKAGE TO DEP.

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WETLANDS AND WATERWAYS REGULATION
WATERWAYS REGULATION PROGRAM

MUNICIPAL PLANNING BOARD NOTIFICATION
APPLICATION FORM 4

____
WATERWAYS FILE NO.

NAME OF APPLICANT ____

PROJECT STREET ADDRESS ____

CITY/TOWN ____

WATERWAY____

(to be completed by Municipal Clerk or Appropriate Municipal Official)

I HEREBY CERTIFY THAT A COPY OF THE COMPLETED WATERWAYS LICENSE APPLICATION AND PLANS DESCRIBED ABOVE WAS SUBMITTED BY THE APPLICANT TO THE MUNICIPAL PLANNING BOARD ON __________________
DATE

SIGNATURE OF MUNICIPAL OFFICIAL ________________________________

TITLE ____

CITY/TOWN OF ____

DATE ____

PLEASE TYPE OR CLEARLY PRINT ALL INFORMATION

NOTICE TO APPLICANT:
THIS FORM MUST BE SUBMITTED ALONG WITH THE ORIGINAL APPLICATION MATERIALS. IF THE FORM CANNOT BE EXECUTED BY THE APPROPRIATE MUNICIPAL OFFICIAL AT THE TIME OF DELIVERY, THE APPLICANT SHOULD WAIT UNTIL HE RECEIVES THE EXECUTED FORM BEFORE SUBMITTING THE COMPLETED APPLICATION PACKAGE TO DEP.

APPENDIX A

MYLAR PLAN SPECIFICATIONS

The following mylar plan specifications shall be strictly adhered to in order to constitute completed plans accompanying a Waterways License application. Any omissions of the required information will result in the Department returning the application without opening the file for regulatory review. These specifications are required in part by the Massachusetts County Registry of Deeds for their recording, and DEP to properly review, authorize and record activities licensed pursuant to G.L. Chapter 91.

1) License plans shall conform to the format and dimensions indicated on the "Sample Plan" contained in this Appendix.

2) License plans shall be drawn on either linen or mylar single matte with a thickness of .004 mils.

3) The minimum letter size on the License Plans shall be one-eighth inch (1/8").

4) Each License Plan sheet shall be marked with the number of the sheet and the total number in the set.

5) License Plan sheet number one shall be the title sheet. The title shall be placed in the lower left corner of sheet one and must read "PLANS ACCOMPANYING PETITION OF ....." stating the full name of the applicant, the structures and/or fill, or change in use to be licensed, and the location of the proposed work (body of water and municipality).

6) License Plans shall be drawn in permanent drawing ink and to a suitable scale to show clearly the proposed structure(s) and/or fill and enough of the shoreline, existing structures and roadways adjacent thereto to define its exact location.

7). The orientation of each License Plan shall be indicated by a north and south line (either true or magnetic).

8). The scale of the License Plan shall be stated or indicated by a graphic (bar) scale on each sheet.

9). Delineations of structures and/or fill shorelines, property lines and state harbor lines.

a. existing structures and/or fill - all existing structures and/or fill within the applicant's property boundaries and within the jurisdiction of Chapter 91 shall be drawn in full black lines. Waterways License numbers authorizing the placement of existing structures and/or fill at the site shall be indicated on the license plan. If no Waterways License was issued for any existing structure and/or fill it shall be so indicated on the plan next that structure or fill. Failure to provide this historic licens information will result in an incomplete filing and the applicatio will be returned. Historic licensing information may be obtained from the appropriate county Registry of Deeds.

b. proposed structures and/or fill, or change in use of existing licensed structures and/or fill - outlines and main features of all structures and/or fill, or change of use to be licensed shall be indicated on the plans in full red lines and designated as "existing" or "proposed". Proposed structures and/or fill shall be shown exactly as they will be built or placed.

c. The Mean High Water or Ordinary High Water shoreline shall be draw on the License Plan along the open shore and the outlines of all existing structures standing in the water at the MHW or OHW and shall be drawn in full black lines and shaded on the water side with a full blue line.

d. The Mean Low Water shoreline shall be drawn on the License Plan by a black dotted line.

e. The Extreme Low Water (MLWS) shoreline shall be drawn on the License Plan by a black dash line. The ELW shoreline shall be determined using the depth contour indicated for the respective coastal municipality indicated in Section IV, Appendix B. Failure to provide the ELW shoreline will result in an incomplete filing and the application will be returned.

f. Applicant's Property Lines - the property boundary lines between the land of the applicant and adjacent lands of other owners, together with the names and addresses of such owners, shall be drawn on the plan in full black lines.

g. State Harbor Commissioner's Lines - any existing State Harbor Commissioner's Line opposite or adjacent to the proposed structures and/or fill to be licensed shall be indicated on the license plan by a black dot and dash line.

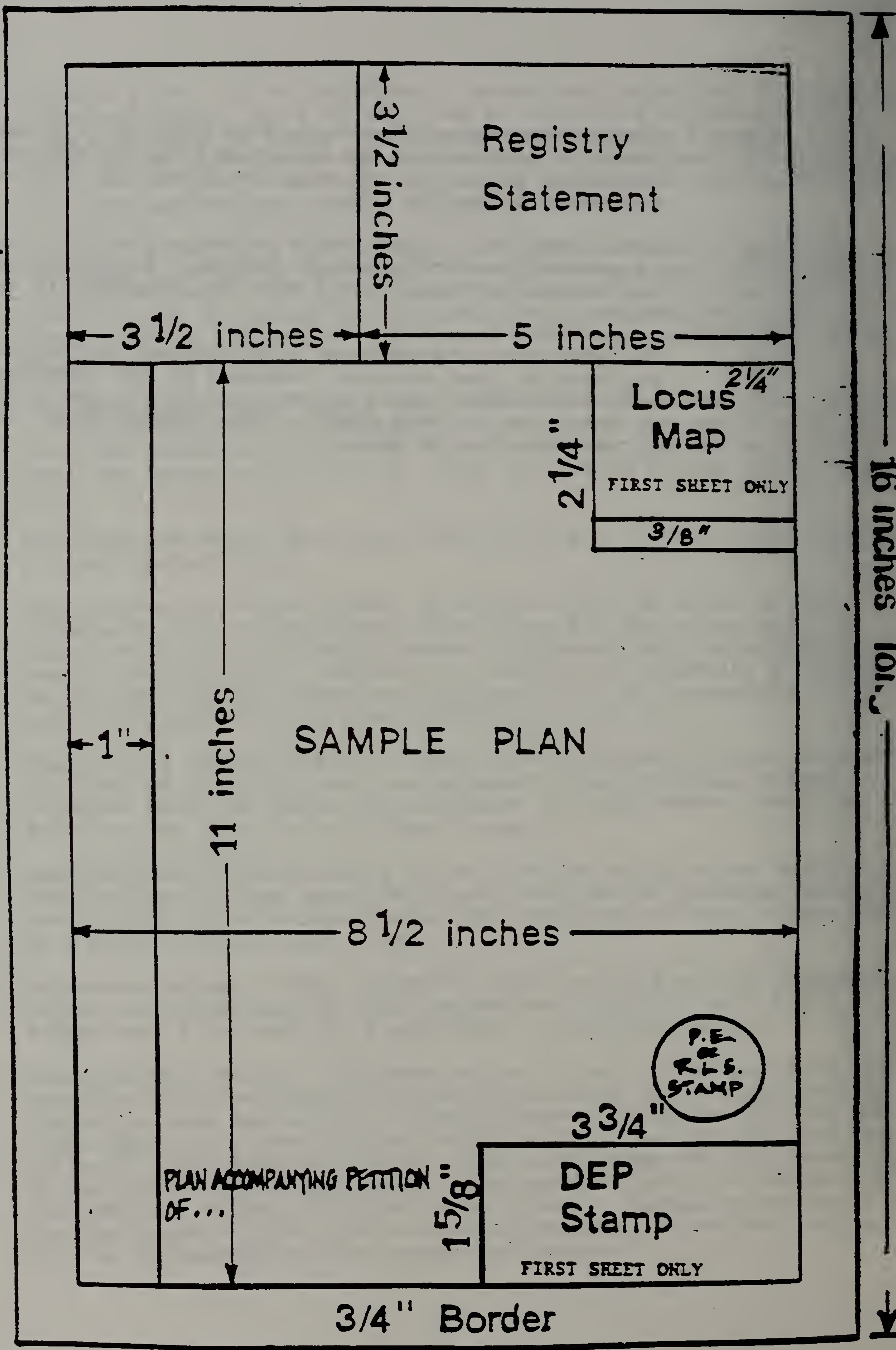
10) Reference Datums - Mean Low Water shall be used as the reference datum for elevations in tidal waters and N.G.V.D. or U.S.G.S. datums shall be used for elevations in non-tidal waters.

11) Cross-Section Views - Accurate and sufficient cross-sections and profiles shall be drawn in black ink to show the general details o the structures and/or fill to be licensed. Both the MHW and MLW lines shall be shown in tidal waters and are to conform with the National Ocean Service (N.O.S.) mean tide range for the locality. In the case of pile structures, the sections shall be sufficient to indicate the number of piles to be driven. Section views shall also indicate finished elevations of proposed structures and/or fill as referenced to the appropriate datum.

12) Actual dimensions of structure(s) and /or fill shall be shown in figures and the distance from the MHW or OHW shoreline to some point near the outer end of the structure(s) and/or fill.

13) Actual volume in cubic yards of any solid fill in cubic yards shall be indicated in figures. Actual volume of any dredged material shall also be indicated in cubic yards.

14) The stamp and signature of a Registered Professional Engineer or Land Surveyor licensed in the Commonwealth of Massachusetts shall be included within the 8 1/2 by 11 inch area of EACH SHEET of the license plan. NO EXCEPTIONS WILL BE MADE!


Registry Statement
3 1/2 inches
3 1/2 inches
5 inches
Locus Map
2 1/4"
2 1/4"
FIRST SHEET ONLY
3/8"
16 inches tot.
1"
11 inches
SAMPLE PLAN
8 1/2 inches
P.E. or R.L.S. STAMP
3 3/4"
DEP Stamp
FIRST SHEET ONLY
1 5/8"
PLAN ACCOMPANYING PETITION OF...
3/4" Border

APPENDIX B

DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATERWAYS REGULATION PROGRAM

EXTREME LOW WATER (MLWS) DEPTH CONTOURS
MASSACHUSETTS COAST
MLW = 0.0

This alphabetical listing of coastal municipalities indicates the computed extreme low water (ELW) depth contours using the 1987 National Ocean Service (NOS) Tide Tables for the East Coast of North America. These depth contours are computed using the Mean Low Water Springs (MLWS) datum. The extreme low water contour for the respective coastal municipality must be indicated on the application's mylar license plan. If the ELW shoreline is not indicated on that plan, the application will be returned for completion.

MUNICIPALITY	EXTREME LOW WATER (MLWS) DEPTH IN FEET MLW = 0.0
Acushnet	- 0.5
Barnstable	- 1.0 (Cape Cod Bay) - 0.5 (Atlantic Side)
Beverly	- 1.0
Boston	- 1.0
Bourne	- 1.0 (Cape Cod Bay) - 0.5 (Buzzards Bay)
Braintree	- 1.0
Brewster	- 1.0
Chatham	- 0.5
Chelsea	- 1.0
Chilmark	- 0.5
Cohasset	- 1.0
Danvers	- 1.0
Darmouth	- 0.5
Dennis	- 1.0 (Cape Cod Bay) - 0.5 (Atlantic Side)
Duxbury	- 1.0
Eastham	- 1.0 (Cape Cod Bay) - 0.5 (Atlantic Side)
Edgartown	- 0.5
Essex	- 1.0
Fairhaven	- 0.5
Fall River	- 0.5
Falmouth	- 0.5
Gay Head	- 0.5
Gloucester	- 1.0
Gosnold	- 0.5
Harwich	- 0.5
Hingham	- 1.0
Hull	- 1.0
Ipswich	- 1.0
Kingston	- 1.0

MUNICIPALITY	EXTREME LOW WATER (MLWS) DEPTH IN FEET MLW = 0.0
Lynn	- 1.0
Manchester	- 1.0
Marblehead	- 1.0
Marion	- 0.5
Marshfield	- 1.0
Mashpee	- 0.5
Milton	- 1.0
Nahant	- 1.0
Nantucket	- 0.5
New Bedford	- 0.5
Newbury	- 1.0
Newburyport	- 1.0
Norwell	- 1.0
Oak Bluffs	- 0.5
Orleans	- 1.0 (Cape Cod Bay) -0.5 (Atlantic Side)
Plymouth	- 1.0
Provincetown	- 1.0 (Cape Cod Bay) -0.5 (Atlantic Side) MHW (Provincelands)
Quincy	- 1.0
Revere	- 1.0
Rockport	- 1.0
Rowley	- 1.0
Salem	- 1.0
Salisbury	- 1.0
Sandwich	- 1.0
Scituate	- 1.0
Somerset	- 0.5
Swampscott	- 1.0
Swansea	- 0.5
Tisbury	- 0.5
Truro	- 1.0 (Cape Cod Bay) -0.5 (Atlantic Side)
Wareham	- 0.5
Wellfleet	- 0.5
Westport	- 0.5
West Tisbury	- 0.5
Winthrop	- 1.0
Weymouth	- 1.0
Yarmouth	- 1.0 (Cape Cod Bay) - 0.5 (Nantucket Sound)

APPENDIX C

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WETLANDS AND WATERWAYS
WATERWAYS REGULATION PROGRAM

WATERWAYS LICENSE APPLICATION CHECKLIST

DO NOT SUBMIT TO DEP

ACTIVITY	DATE COMPLETED
1) APLICATION FORM COMPLETED, SIGNED AND SUBMITTED	
2) DREDGING ADDENDUM COMPLETED, SIGNED AND SUBMITTED	
3) MYLAR PLANS SUBMITTED	
4) MUNICIPAL ZONING CERTIFICATION SUBMITTED (IF APPLICABLE)	
5) MUNICIPAL PLANNING BOARD NOTIFICATION SUBMITTED (IF APPLICABLE)	
6) VALID ORDER OF CONDITIONS SUBMITTED	
7) TEXT OF PUBLIC NOTICE RECEIVED FROM DEP	
8) PUBLIC NOTICE PUBLISHED IN NEWSPAPER AND PROOF OF PUBLICATION SUBMITTED	
9) WATER QUALITY CERTIFICATION OR NPDES PERMIT SUBMITTED (IF APPLICABLE)	
10) MEPA REVIEW COMPLETED (IF APPLICABLE)	
11) TIDELANDS CHARGES PAID TO DEP (IF APPLICABLE)	
12) LICENSE RECEIVED FROM DEP	
13) LICENSE AND PLANS RECORDED IN REGISTRY OF DEEDS	
14) DEP NOTIFIED OF BOOK NUMBER, PAGE NUMBER AND DATE OF RECORDING (IN WRITING)	
15) DEP NOTIFIED IN WRITING OF THE DATE THE AUTHORIZED WORK IS COMPLETED	

FOR APPLICANT'S USE ONLY

WATER QUALITY CERTIFICATION APPLICATION

9.90: Appendix A - Standard Application Form

Part I - Standard Application

1) Name and Address of Applicant: ______________________________

____

____

Telephone Number: ______________________________

2) Name and Address of Authorized Agent, if any: ______________________

____

____

Telephone Number: ______________________________

3) Description of Proposed Dredging Site:

A) Describe in detail the proposed project or activity, including the location, the purpose and intended use of the project, identification of the waters of the Commonwealth affected by the project, and the water quality classification applicable to those waters.

____

____

____

____

____

____

____

____

____

____

Date Activity to commence ________ Date Activity to be completed ________

B) Attach a plan(s) of the proposed project drawn as follows:

9.90: continued

Vicinity Map. Identify the map or chart from which the vicinity map was taken and show the following:

____ Location of the activity site including latitude and longitude and river mile, if known.

____ Name of waterway.

____ All applicable political (county, borough, town, city, etc.) boundary lines.

____ Name of and distance to local town, community, or other identifying location.

____ Names of all roads in the vicinity of the site.

____ Graphic scale.

____ North arrow.

Plan View. The plan view of the proposed activity should show the following:

____ Existing shorelines.

____ Ebb and flood in tidal waters and direction of flow in rivers.

____ North arrow.

____ Graphic or numerical scale.

____ Mean high and low water lines if the proposed activity is located in tidal areas.

____ Ordinary high water line and ordinary low water line if the proposed activity is on a lake or ordinary high water if on a stream.

____ Water depths around the project.

____ Principal dimensions of the structure or work and extent of encroachment beyond the applicable high water line.

____ Waterward dimension from an existing permanent fixed structure or object.

9.90: continued

____ Distance between proposed activity and navigation channel, where applicable.

____ Harbor lines, if established and if known.

____ Location of structures, if any, in navigable waters immediately adjacent to the proposed activity.

____ Location of any wetlands, swamps, marshes, etc. Identify.

____ Proximity to any designated areas of critical environmental concern/Areas for Preservation or Restoration (ACEC/APR) (See CZM regulations)

Elevation and/or Section View. The elevation and/or section view of the proposed project should show the following:

____ Same water elevations as in the plan view.

____ Depth at waterward face of proposed work. Show dredging grade.

____ Graphic or numerical scale.

____ Cross-section of excavation including approximate side slopes.

C) Physical Description

1. What is the length, width, depth and volume of the proposed project? Length ____________yds, Width ____________yds, Depth ____________yds, Volume ____________cu. yds.

2. Is the proposed project considered (a) a new project or (b) maintenance of an existing project?

3. Describe in complete detail the physical dredging operation including descriptions of the type of dredge equipment, i.e., hopper dredge, hydraulic dredge, etc., the type of transportation to be used from the dredge site to the disposal site, the method of release of the dredged material into the disposal site, and the name of the contractor if other than the applicant.

9.90: continued

D) Historical Parameters

1. To the best of your knowledge, does the proposed project area have any past history of:

a) chemical or oil spills or discharge? Yes ___ No ___

b) upstream or on-site industrial or municipal discharge Yes ___ No ___

c) chronic pollutant loading from port or harbor use and/or other indirect sources of pollutants? Yes ___ No ___

To expedite processing for any affirmative answer, provide as much historical information as you have, including dates, amounts, concentrations, etc., of such spills or discharge.

2. What is the expected frequency of maintenance dredging of this project? Explain.

9.90: continued

4) Description of Material to be Dredged

A) Grain Size Analysis

A complete grain size analysis of the material to be dredged is required. A single pooled representative sample will be analyzed initially. Based on the size and location of the project and the results of this initial analysis, the Division may require additional samples to be analyzed subsequently.

Size Fraction	% of total by weight
coarse gravel 64 mm	
fine gravel 2-64 mm	
sand .063-2 mm	
silt .004-063 mm	
clay .004 mm	

B) Chemical Analysis of Sediment

A complete bulk analysis of the material to be dredged is required. A single pooled representative sample will be analyzed initially. Based on the size and location of the project and the results of this initial analysis, the Division may require additional samples to be analyzed subsequently.

% volatile solids	
% oil and grease	
mercury (ppm)	
cadmium "	
lead "	
chromium "	
copper "	

State test methods used for each test in A) and B) above, and name person conducting test.

9.90: continued

5) Description of the Disposal Site for Dredged Material.

A) Location of proposed disposal site and its physical boundaries.

B) Has the site been designated by the state or E.P.A. as a dredge disposal site? Yes ___ No ___

If yes, supply any available documentation as to effects of other authorized dumpings that have been made in the dumping area (e.g., heavy metal background reading and organic carbon content).

If no, give a description of the characteristics of the proposed disposal site and an explanation as to why no previously designated site is feasible.

C) Is anticipated disposal site located within a designated ocean sanctuary as established by federal law or G. L. c. 132A, § 13? Yes ___ No ___ If yes, which sanctuary?

D) If disposal is anticipated to occur on land, indicate drainage characteristics from the results of test pits, borings and percolation tests as applicable.

E) How long is disposal site estimated to be in use? Indicate the duration of this disposal action and anticipated future use of site.

F) Include plans of proposed site as described in Item 3(b) above, unless ocean site is proposed. If land disposal is proposed, include plans for effluent control at the disposal site.

9.90: continued

Application is hereby made for Water Quality Certification concerning the activities described herein. I certify that I am familiar with the information contained in this application, and that to the best of my knowledge and belief such information is true, complete, and accurate. I further certify that I possess the authority to undertake the proposed activities.

Date	Signature of Applicant or Authorized Agent

The application must be signed by the applicant; however, it may be signed by a duly authorized agent (named in Item 2) if this form is accompanied by a statement by the applicant designating the agent and agreeing to furnish upon request, supplemental information in support of the application.

9.91: Appendix B - Supplemental Information Form

MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

Application for Certification for Dredging, Dredge Material Disposal and Filling Projects.

Part II - Supplemental Information

1) Name and Address of Applicant: ____________________

____

____

2) EOEA No. ____________________

3) Location of Project: ____________________

____

____

4) Chemical Analysis of Dredge Site Sediment.

A) A complete bulk analysis of the material to be dredged is to be completed for ____ representative sample(s) taken as specified by the Division below.

Sampling instructions: ____________________

____

____

Analyses are to be completed and reported, including test method used and person performing test, for the following:

Specific gravity ____________
% Total solids ____________
% Suspended solids ____________
% Volatile solids ____________
% Water ____________
% Oil and grease ____________
Mercury (ppm) ____________
Cadmium " ____________
Lead " ____________
Arsenic " ____________
Chromium " ____________
Copper " ____________
Nickel " ____________
Vanadium " ____________

Ammonia ____________
TKN ____________
Phenol ____________
Phosphorus ____________
Sulfide ____________
PCB's ____________
Pesticides ____________
(specify if present)
Other ____________
____
____
____
____
____

9.91: continued

B) **Biochemical Analysis**

The applicant will supply the following analytical results based on a statistically representative single (initially) sample of the material to be dredged.

1. Biological Oxygen Demand ____________ mg/g
2. Chemical Oxygen Demand ____________ mg/g
3. Liquid Phase Bioassay ____________
4. Suspended Particulate Phase Bioassay ____________
5. Solid Phase Bioassay ____________
6. Bioaccumulation Potential

   Pesticides ____________
   Mercury ____________
   Cadmium ____________
   Petroleum ____________
   Other ____________

7. Elutriate Test Results

5) Other (as specified by the Division)

6) I certify that I am familiar with the information contained in this application, and that to the best of my knowledge and belief such information is true, complete, and accurate.

________________________ ________________________________

Date Signature of Applicant or Authorized Agent

REGULATORY AUTHORITY

314 CMR 9.00: M.G.L. c. 21, ss. 26 - 53.

FOR DIVISION USE ONLY
License Number:
Date:
Processed By:

APPLICATION FOR LICENSE TO APPLY CHEMICALS FOR CONTROL OF NUISANCE AQUATIC VEGETATION

MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATER POLLUTION CONTROL
TECHNICAL SERVICES BRANCH
LYMAN SCHOOL, WESTBOROUGH, MA 01581
Telephone No. (508) 792-7470, ext. 63

Instructions: Pursuant to the authority granted to the Department of Environmental Quality Engineering, (hereinafter called the Department), by Massachusetts G.L.c. 111, s5E, a license is required for application of chemicals to waterbodies for the control of nuisance aquatic vegetation, except under the following conditions:

(1) When treatment is undertaken by employees and agents of the Departments of Environmental Quality Engineering, Environmental Management, and Fisheries, Wildlife and Recreational Vehicles or of the state Reclamation Board or of related Federal agencies, while in the conduct of their official duties; or

(2) When treatment is undertaken with algicides approved by the Department and used by legally established water supply agencies to control taste and odors; and

(3) When treatment is undertaken in privately owned ponds from which there are no flowing outlets.

Although a license is not required under the aforementioned conditions, any state or municipal agency or private person planning a herbicide application to a waterbody exempt from this license requirement is requested to inform the Department by letter of such treatment for the purpose of record keeping.

This license application to chemically treat waters for control of nuisance aquatic vegetation must be completed and submitted to the Division of Water Pollution Control, Technical Services Branch (address above) at least thirty (30) days prior to the proposed date(s) of treatment.

1. Name of Licensed Applicator: ______________________

Address: ______________________

____

Telephone No.: ______________________

Pesticide Bureau License No.: ______________________

2. Representing Project Proponent: ______________________
(e.g. town, lake association, or private party)

Telephone No.: ______________________

3. Date Submitted: ______________________

4. **Proposed date(s) of treatment:** ____________________

5. **Name of waterbody:** ____________________

6. **Location of waterbody (city/town):** ____________________

7. **Area of waterbody (acres):** ____________________

8. **Maximum depth:** __________ **Mean depth:** __________

9. **Description of ownership of waterbody (check one):**

   a. Great Pond __________

   b. Great Pond enhanced by flowage __________

   c. Private Pond (with flowing outlet) __________

   d. Other (please describe) ____________________

10. **Extent of proposed treatment (check one) and provide acreage to be treated.**

a. Entire waterbody:	__________	acres: __________
b. Entire shoreline:	__________	acres: __________
c. Partial treatment:	__________	acres: __________

11. **A map of the waterbody must be submitted with this application. This map should be of good quality and must contain the following information:**

   a. Relative abundance and species composition of vegetation in the pre-treatment area.

   b. If partial treatment is proposed, the map must clearly show the areas to be treated.

   c. Location of all public and private bathing beaches.

   d. Name and location of any public and/or private water supply wells or intakes within 300 feet of the shoreline.

   e. Location of all inlet and outlet streams.

   f. Location of any livestock watering or access areas.

   g. If separate areas of the waterbody are to be treated with different chemicals, then this information must be clearly indicated.

12. **Is water from lake/pond used for (circle all that apply):**

a. Private water supply?	YES	NO	b. Contact recreation?	YES	NO
c. Watering livestock?	YES	NO	d. Irrigation?	YES	NO

13. Describe any uses made of the outlet waters within one mile of the outlet.

____

____

____

14. List the vegetation to be controlled in descending order of abundance (genus name of macrophyton and/or major phytoplankton groups).

a. ____________	e. ____________
b. ____________	f. ____________
c. ____________	g. ____________
d. ____________	h. ____________

15. Chemical Information:

	#1	#2	#3	#4
Chemical Name(s) (trade name)				
Chemical Form (dry/liquid)				
Total Weight/Volume Applied(lbs/gallons)				
Acres Treated (for each chemical)				
Application Rate (lbs or gal/acres)				
Planned Maximum Concentration(ppm)				

16. Briefly describe treatment method including any additional information on chemicals applied or remarks concerning this particular treatment.

____

____

____

____

17. The applicant is hereby advised of the following:

a. Within fourteen (14) days of the date of treatment authorized in this license, the licensee is required to submit a written report to the Department certifying the treatment date, application rate, and the total weight/volume for each chemical used in the treatment.

b. The licensee shall not apply chemicals in a manner contrary to, or inconsistent with, the application conditions set forth in Section I.A. in the license without the prior written approval of the Department.

c. The applicant is hereby notified that chemical treatments to control aquatic nuisances in public or private lakes and ponds of the Commonwealth involve the alteration of wetland resource areas protected under Massachusetts G.L.c. 131, s40, the Wetlands Protection Act, and 310 CMR 10.00, Massachusetts Wetlands Protection Regulations.

d. A final Order of Conditions or a Negative Determination of Applicability must be obtained from the local Conservation Commission prior to application of chemicals under any license issued by the Department.

e. Shoreline areas of the lake must be posted with signs warning the general public of any water use restrictions stated on the chemical label for a minimum of one week. This is especially important at bathing beaches and other areas of common access. These signs shall clearly state that the chemical treatment is being conducted pursuant to a license issued by the Department of Environmental Quality Engineering, "DEQE".

f. The Department may require the licensee to cease application of chemicals to a body of water at any time following the issuance of a license if the Department determines that chemical treatment will be ineffective, or will result in unreasonable restrictions on current water uses, or will produce unnecessary adverse side effects on nontarget vegetation.

g. Chemical applications shall be performed in accordance with the manufacturer's label directions, existing pesticide use laws, and any conditions imposed by local or state agencies.

h. Chemical treatments shall only be performed by an applicator currently licensed by the Massachusetts Department of Food and Agriculture Pesticide Bureau in the aquatic weed category.

i. Issuance of a license does not release the licensee from liability resulting from the use of chemicals or from negligent or reckless application of chemicals specified in this application.

The applicant hereby certifies the truth of the above statements and agrees to accept the following conditions as a prerequisite to the issuance of a license: that the issuance of the license is based on the accuracy of all statements presented by the applicant; that damage resulting from the inaccuracy of any computations, improper application of the chemical(s), or legal responsibility for the representations made in obtaining required approvals or releases, or failure to obtain said approvals or releases is the sole responsibility of the applicant.

____________________	____________________
Printed name of Applicant	**Title**
____________________	____________________
Signature of Applicant	**Date Signed**

OR REVIEW ONLY

LICENSE TO APPLY CHEMICALS FOR CONTROL OF NUISANCE AQUATIC VEGETATION

MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER POLLUTION CONTROL
WESTBOROUGH, MA. 01581
Telephone No. (508) 792-7470

Name and Address of Applicant: ______________________________

____

____

Application/License No.: ______________________________

Date of Application: ______________________________

Date of Issuance: ______________________________

Date of Expiration: ______________________________

Name of Lake: ______________________________

Location of Lake (City/Town): ______________________________

AUTHORITY FOR ISSUANCE

Pursuant to the authority granted to the Department of Environmental Protection, by Massachusetts G.L.c. 111, s5E. the following license is hereby issued to: ______________________________ (hereinafter called the "licensee"), authorizing the application of chemicals for the control of nutrients, algae or aquatic plants to: ______________________________ (lake or pond) such authorization being expressly conditional on compliance by the licensee with all terms and conditions of the license hereinafter set forth. This license shall become effective on the date of the Director's signature and shall expire six months from the date of issuance.

______________________________ ______________

Arleen O' Donnell, Acting Director **Date**
Division of Water Pollution Control
Department of Environmental Protection

FOR REVIEW ONLY

I. SPECIAL CONDITIONS

A. Application Conditions

	#1	#2	#3	#4
CHEMICAL NAME(S):				
MAXIMUM WEIGHT OR VOLUME:				
MAXIMUM APPLICATION RATE(S):				
MAXIMUM TREATMENT ACRES:				
TREATMENT DATE(S):				

B. Application Report

Within fourteen (14) days of the date of treatment, the licensee shall submit a written report to the Department certifying the treatment date, application rate, and the total weight/volume for each chemical used in the treatment, in accordance with requirements of Section I.A. of this license.

C. Modification of Application Conditions

The licensee shall not apply chemicals in a manner contrary to, or inconsistent with, the application conditions set forth in Section I.A. of this license without the prior written approval of the Department.

D. Other Special Treatment Conditions

The licensee shall abide by the following special conditions for this treatment:

II. GENERAL CONDITIONS

A. The licensee is hereby notified that chemical treatments to control aquatic nuisances in public or private lakes and ponds of the Commonwealth involve the alteration of wetland resource areas protected under both Massachusetts G.L.c. 131, s40, the Wetlands Protection Act and 310 CMR 10.00, Massachusetts Wetlands Protection Regulations.

B. The licensee is hereby notified that issuance of this license does not in any way constitute the Department's approval of the chemical treatment as it relates to the provisions of the Wetlands Protection Act.

C. The licensee shall obtain either a final Order of Conditions or a negative Determination of Applicability from the ______________________________ Conservation Commission prior to application of chemicals authorized under this license.

R REVIEW ONL

D. Shoreline areas of the lake or pond must be posted with signs warning the general public of any water use restrictions stated on the chemical label for a minimum of one week. This is especially important at bathing beaches and other areas of common access. These signs shall clearly state that the chemical treatment is being conducted pursuant to a license issued by the Department of Environmental Protection, "DEP."

E. The Department may require the licensee to cease application of chemicals to a body of water at any time following the issuance of a license if the Department determines that the chemical treatment will be ineffective, or will result in unreasonable restrictions on current water uses, or will produce unnecessary adverse side effects on nontarget flora or fauna.

F. Chemical applications shall be performed in accordance with the manufacturer's label directions, existing pesticide use laws, and any conditions imposed by other local or state agencies.

G. Chemical treatments shall only be performed by an applicator currently licensed by the Massachusetts Department of Food and Agriculture Pesticide Bureau in the aquatic weed category.

H. Issuance of this license does not release the licensee from liability resulting from the use chemicals or from negligent or reckless application of chemicals specified in section I.A. of this license.

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Management

P.O. Box 173
d Common Road
ncaster, MA
0523

(17) 727-0627

am Safety Program

APPLICATION FOR AUTHORIZATION TO CONSTRUCT OR ALTER A RESERVOIR, RESERVIOR DAM OR MILL DAM

Jurisdiction:

General Laws: Chapter 253, s.44 et seq. as amended by
Chapter 706 of the Acts of 1975
Chapter 720 of the Acts of 1979

The approval of the Commissioner shall not apply to small dams, constructed for irrigation or for other purposes, the breaking of which would involve no risk to life or property, not to standpipes or tanks, nor to a dam where the area draining into the pond formed thereby does not exceed one square mile; unless the dam is more than ten feet in height above the natural bed of the stream at any point, or unless the quantity of water which the dam impounds exceeds one million gallons. However, information must be submitted to enable the Commissioner to determine whether approval is necessary.

Approval of this plan does not release the applicant from the requirements of Chapter 91, or Chapter 131 of the Massachusetts General Law.

Part "A"

JURISDICTIONAL DETERMINATION
(check the appropriate column)

	Yes	No
1. Is there a risk to life and property downstream in the event of failure?		
2. Does the area draining into the pond exceed one square mile ?		
3. Does the height of the dam exceed 10 ft. above the natural bed of the stream at any point?		
4. Does the volumn of water impounded at maximum pool level exceed one million gallons?		

If the answer to any one of the above questions is Yes, then the Commissioner of Department of Environmental Management has jurisdiction. Proceed with Part B of this application.

If the answers to all four of the above questions are No, please submit backup information for a review by this Department for our jurisdictional determination. The backup information should include at least:

a. A copy of a topographic map clearly indicating the location of the dam and the effective drainage area.

b. A sketch showing the maximum section of the dam indicating its height, as measured from the lowest point of the streambed.

c. Calculations for the volume of water impounded at the maximum design pool level.

d. A brief statement pertaining to downstream conditions with respect to risk to life and property.

e. The signature of applicant and engineer.

Part "B"

GENERAL INFORMATION

1. Location (City-Town):______________________________

2. Detailed description of dam location:

____

____

____

____

3. Present or Prospective Owner(s):

Name(s)___________________________________

Street ___________________________________

City/Town___________ State ___________ Zip ______

Telephone_________________________________

4. Name of U.S. Geological Survey Map Quadrangle:

____

5. Name of Reservoir or Waterway:________________________

6. Is there specific legislative authority to construct the dam?

Yes ( ) Indentify_________________________

No ( )

7. Purpose for the dam:_______________________________

8. Nature of the work:

Proposed dam ( )
Alteration of existing dam ( )
Major repair of existing dam ( )
Regular maintenance ( ) If checked go to Part "C"

Part "B" (continued)

HAZARD EVALUATION

(Downstream Field Investigation)

1. The estimated number of people that could be affected by overtopping or failure of the structure, and to what degree they would be affected.

____

____

____

____

2. The number of properties (homes, buildings etc.) and the estimated extent of damage by overtopping or failure. ____________

____

____

____

3. Roads (type) or other structures that could be affected by overtopping or failure. ____________________

____

____

____

4. Additional Information:

Part "B" (continued)

HYDROLOGIC CONSIDERATIONS

Procedures for hydrologic design as contained in the latest edition of the U.S. Department of the Interior, Bureau of Reclamation "Design of Small Dams".

1. Peak Outflow ________________________ c.f.s..
2. Design Storm Duration ________________________.
3. Rainfall Intensity ________________________ "/hr. .
   Percent Runoff ________ % ________________ inches.
4. Contributory Drainage Area ________________ sq. mi.
   (Attach a copy of U.S. Topographic Map with the outline of the drainage divide).
5. Previous Known Flood of Record
   (month) __________ (year) ______________
6. Design Maximum Flood Level Elevation ______________.
7. Additional Information:

Part "B" (continued)

DESIGN CRITERIA

1. Datum used:
   (a) M.S.L. of 1929 ____________________.
   (b) Assumed ____________________.
   (c) Other ____________________.

2. Maximum height of the dam ____________________ft.
   (a) Top elevation of dam ____________________.
   (b) Top elevation of spillway ____________________.

3. Volume of water impounded, at maximum design pool level. ____________________ gallons

4. Present river bed or channel elevation @ dam ____________________.

5. Normal pool elev. ____________________.
   surface area ____________________ac.

6. Maximum pool elev. ____________________.
   surface area ____________________ac.

7. Type of structure (earth, concrete, etc.)
   ____.

8. Crest width ____________________ft.

9. Freeboard, as measured from the maximum design pool level ____________________.

10. Length of principal spillway ____________________.

11. Description of principal spillway ____________________.
    ____.

Part "B" (continued)

Design Criteria

12. Emergency spillway Yes ( ) No ( )
If yes, describe ____.

13. Gates Yes ( ) Number __________. Size ___________.
No ( )

14. Nature of slope protection
(riprap, vegetated etc.) ________________________________.

15. Stop log structure(s)
Yes ( ) Mechanical ( ) Manual ( )
No ( )

SUBSURFACE INVESTIGATION

Boring logs, analysis and recommendations to accompany this application.

CONSTRUCTION DRAWINGS

Names & addresses of property owners for all parcels of land within the flowage area must be clearly indicated on the plan. Submit 2 copies with this application.

Part "B" (continued)

SIGNATURE SHEET

APPLICANT

Name ____

Street ____

City/Town ____________________ State ____________ Zip __________

Telephone ____

Signature ______________________________ Date __________

DESIGN ENGINEER

Name ____

Street ____

City/Town ____________________ State ____________ Zip __________

Telephone ____

Signature ______________________________ Date __________

*Engineer's Stamp must be included.

Upon receipt of this required apllication a prompt determination will be made on issuing a permit to proceed. Conditions of such a permit will be contingent upon the nature of proposed work.

*ENGINEER'S STAMP:

Part "C"

REGULAR MAINTENANCE

If the proposed work involves regular maintenance activities (i.e. The proposed work does not materially alter the dam.) a permit is not required.

Typical maintenance activities include, but are not limited to the following items.

Please indicate the nature of proposed maintenance and return the complete application. Use additional paper if necessary.

	NO	YES
Surface cracks?	______	______
Slumping or cracking on the upstream or downstream side?	______	______
Erosion from runoff, wave action or traffic?	______	______
Embankment/spillway seepage?	______	______
Water muddy?	______	______
Top of dam settled?	______	______
Loss of riprap?	______	______
Tress, brush, or burrows on embankment?	______	______
Spillways blocked?	______	______
Exposed metal rusty?	______	______
Concrete deterioration or cracks?	______	______
Cracks or uneven movement?	______	______
Scour?	______	______
Pipe joint separation?	______	______
Gates operational?	______	______
Trash racks blocked?	______	______

LOCATION OF PROPERTY

1. Location (City-Town)____________________________________
2. Registry of Deeds Book ______________ Page ____________
3. Locus Map: please attach.

11.28: Environmental Notification Form

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name ______________________________
   Address/Location ______________________________
   ____
   City/Town ______________________________
2. Project Proponent ______________________________
   Address ______________________________
3. Est. Commencement ______________ . Est. Completion ______________ .
   Approx. Cost $ __________ . Status of Project Design __________ % Complete.
4. Amount (if any) of bordering vegetated wetlands, salt marsh, or tidelands to be dredged, filled, removed, or altered (other than by receipt of runoff) as a result of the project.
   __________ acres __________ square feet.
5. This project is categorically included and therefore requires preparation of an EIR.
   Yes ______ No ______ ?

B. Narrative Project Description

Describe project and site.

Copies of the complete ENF may be obtained from (proponent or agent):
Name: ______________________ Firm/Agency: ______________________
Address: ______________________ Phone No. ______________________

1986 THIS IS AN IMPORTANT NOTICE. COMMENT PERIOD IS LIMITED.
For Information, call (617) 727-5830

11.28: continued

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C. List the State or Federal agencies from which permits or other actions have been/will be sought:

Agency Name	Permit	Date filed; file no.

D. List any government agencies or programs from which the proponent will seek financial assistance for this project:

Agency Name	Funding Amount

E. Areas of potential impact (complete Sections II and III first, before completing this section).

1. Check all areas in which, in the proponent's judgment, an impact of this project may occur. Positive impacts, as well as adverse impacts, may be indicated.

	Construction Impacts	Long Term Impacts
Inland Wetlands		
Coastal Wetlands/Beaches		
Tidelands		
Traffic		
Open Space/Recreation		
Historical/Archaeological		
Fisheries/Wildlife		
Vegetation/Trees		
Agricultural Lands		
Water Pollution		
Water Supply/Use		
Solid Waste		
Hazardous Materials		
Air Pollution		
Noise		
Wind/Shadow		
Aesthetics		
Growth Impacts		
Community/Housing and the Built Environment		
Other (Specify)		

2. List the alternatives which have been considered.

11.28: continued

P.3

F. Has this project been filed with EOEA before? No ______ Yes ______ EOEA No. ______

G. WETLANDS AND WATERWAYS

1. Will an Order of Conditions under the Wetlands Protection Act (c.131s.40) or a License under the Waterways Act (c.91) be required?
   Yes ______ No ______
2. Has a local Order of Conditions been:
   a. issued? Date of issuance ______ ; DEQE File No. ______ .
   b. appealed? Yes ______ ; No ______ .
3. Will a variance from the Wetlands or Waterways Regulations be required? Yes ______ ; No ______ .

II. PROJECT DESCRIPTION.

A. Map; site plan. Include an original 8½ x 11 inch or larger section of the most recent U.S.G.S. 7.5 minute series scale topographic map with the project area location and boundaries clearly shown. If available, attach a site plan of the proposed project.

B. State total area of project: ______________ acres.
Estimate the number of acres (to the nearest 1/10 acre) directly affected that are currently:
1. Developed .... ______ acres
2. Open Space/
   Woodlands/Recreation ______ acres
3. Wetlands .... ______ acres
4. Floodplain .... ______ acres
5. Coastal Area .... ______ acres
6. Tidelands .... ______ acres
7. Productive Resources
   Agriculture .... ______ acres
   Forestry .... ______ acres
8. Other .... ______ acres

C. Provide the following dimensions, if applicable:

	Existing	Increase	Total
Length in miles	______	______	______
Number of Housing Units	______	______	______
Number of Stories	______	______	______
Gross Floor Area in square feet	______	______	______
Number of parking spaces	______	______	______
Total of Daily vehicle trips to and from site (Total Trip Ends)	______	______	______
Estimated Average Daily Traffic on road(s) serving site	______	______	______
1. ______________________	______	______	______
2. ______________________	______	______	______
3. ______________________	______	______	______

D. TRAFFIC PLAN. If the proposed project will require any permit for access to local roads or state highways, attach a sketch showing the location and layout of the proposed driveway(s).

11.28: continued

P.4

III. ASSESSMENT OF POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

Instructions: Explain direct and indirect adverse impacts, including those arising from general construction and operations. For every answer explain why significant adverse impact is considered likely or unlikely to result. Positive impact may also be listed and explained.

Also, state the source of information or other basis for the answers supplied. Such environmental information should be acquired at least in part by field inspection.

A. Open Space and Recreation

1. Might the project affect the condition, use, or access to any open space and/or recreation area?

   Explanation and Source:

2. Is the project site within 500 feet of any public open space, recreation, or conservation land?

   Explanation and Source:

B. Historic and Archaeological Resources

1. Might any site or structure of historic significance be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

   Explanation and Source:

2. Might any archaeological site be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

   Explanation and Source:

C. Ecological Effects

1. Might the project significantly affect fisheries or wildlife, especially any rare or endangered species? (Prior consultation with the Massachusetts Natural Heritage Program is advised).

   Explanation and Source:

11.28: continued

P.5

2. **Might the project significantly affect vegetation, especially any rare or endangered species of plant? (Prior consultation with the Massachusetts Natural Heritage Program is advised.)**
   (Estimate approximate number of mature trees to be removed: ______________)
   Explanation and Source:

3. **Agricultural Land. Has any portion of the site been in agricultural use within the last 15 years? If yes, specify use and acreage.**
   Explanation and Source:

D. Water Quality and Quantity

1. **Might the project result in significant changes in drainage patterns?**
   Explanation and Source:

2. **Might the project result in the introduction of any pollutants, including sediments, into marine waters, surface fresh waters or ground water?**
   Explanation and Source:

3. **Does the project involve any dredging? No ______ Yes ______Volume ______ . If 10,000 cy or more, attach completed Standard Application Form for Water Quality Certification, Part I (314 CMR 9.02(3), 9.90, DEQE Division of Water Pollution Control).**

11.28: continued

P.6

4. Will any part of the project be located in flowed or filled tidelands, Great Ponds, or other waterways? (Prior consultation with the DEQE and CZM is advised.)

Explanation and Source:

5. Will the project generate or convey sanitary sewage? No ______ Yes ______

If Yes, Quantity: ________ gallons per day

Disposal by: (a) Onsite septic systems .... Yes ______ No ______

(b) Public sewerage systems (location: average and peak daily flows to treatment works) .... Yes ______ No ______

Explanation and Source:

6. Might the project result in an increase in paved or impervious surface over a sole source aquifer or an aquifer recognized as an important present or future source of water supply?

Explanation and Source:

7. Is the project in the watershed of any surface water body used as a drinking water supply?

Explanation and Source:

8. Are there any public or private drinking water wells within a 1/2-mile radius of the proposed project?

Explanation and Source:

11.28: continued

P.7

9. Does the operation of the project result in any increased consumption of water?
   Approximate consumption ________ gallons per day. Likely water source(s) ________
   Explanation and Source:

E. Solid Waste and Hazardous Materials

1. Estimate types and approximate amounts of waste materials generated, e.g., industrial, domestic, hospital, sewage sludge, construction debris from demolished structures. How/where will such waste be disposed of?
   Explanation and Source:

2. Might the project involve the generation, use, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source:

3. Has the site previously been used for the use, generation, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source:

F. Energy Use and Air Quality

1. Will space heating be provided for the project? If so, describe the type, energy source, and approximate energy consumption.
   Explanation and Source:

11.28: continued

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2. **Will the project require process heat or steam? If so, describe the proposed system, the fuel type, and approximate fuel usage.**

   Explanation and Source:

3. **Does the project include industrial processes that will release air contaminants to the atmosphere? If so, describe the process (type, material released, and quantity released).**

   Explanation and Source:

4. **Are there any other sources of air contamination associated with the project (e.g. automobile traffic, aircraft traffic, volatile organic compound storage, construction dust)?**

   Explanation and Source:

5. **Are there any sensitive receptors (e.g. hospitals, schools, residential areas) which would be affected by air contamination caused by the project?**

   Explanation and Source:

G. Noise

1. **Might the project result in the generation of noise?**

   (Include any source of noise during construction or operation, e.g., engine exhaust, pile driving, traffic.)

   Explanation and Source:

11.28: continued

P.9

2. Are there any sensitive receptors (e.g., hospitals, schools, residential areas) which would be affected by any noise caused by the project?
   Explanation and Source:

3. Is the project a sensitive receptor, sited in an area of significant ambient noise?
   Explanation and Source:

H. Wind and Shadow
1. Might the project cause wind and shadow impacts on adjacent properties?
   Explanation and Source:

I. Aesthetics
1. Are there any proposed structures which might be considered incompatible with existing adjacent structures in the vicinity in terms of size, physical proportion and scale, or significant differences in land use?
   Explanation and Source:

2. Might the project impair visual access to waterfront or other scenic areas?
   Explanation and Source:

11.28: continued

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IV. CONSISTENCY WITH PRESENT PLANNING

Discuss consistency with current federal, state and local land use, transportation, open space, recreation and environmental plans and policies. Consult with local or regional planning authorities where appropriate.

V. FINDINGS AND CERTIFICATION

A. The public notice of environmental review has been/will be published in the following newspaper(s):

(NAME) ____________________ (Date) ____________________

____________________ ____________________

____________________ ____________________

B. This form has been circulated to all agencies and persons as required by 301 CMR 11.24.

____________	____________________	____________	____________________
Date	Signature of Responsible Officer or Project Proponent	Date	Signature of person preparing ENF (if different from above)
	____________________		____________________
	Name (print or type)		Name (print or type)
	Address ____________		Address ____________
	____________		____________
	Telephone Number ________		Telephone Number ________

RELATED PUBLICATIONS

CONTROLLING URBAN RUNOFF:

A Practical Manual for Planning and Designing Urban BMPs

by

Thomas R. Schueler

Department of Environmental Programs
Metropolitan Washington Council of Governments

prepared for

Washington Metropolitan Water Resources Planning Board

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CHAPTER 2: CHOOSING THE BEST BMP OPTION FOR A SITE

This chapter outlines factors that planners and engineers need to consider when choosing an urban best management practice (BMP) for a particular development site. It begins with a brief discussion of the minimum objectives that a BMP plan for a site should meet. The next section provides a series of screening tools that can be used to select the most appropriate BMP for a particular development site. These screening tools can be used to evaluate the following:

- BMP options that are suitable for a site, given its physical condition and development status.
- Stormwater control benefits provided by each BMP option.
- The expected pollutant removal capability for each BMP option, under several different design scenarios.
- Environmental and human amenity values associated with the BMP option selected.

The screening tools can be used in any order, or may be used as an overall summary of BMP performance. Several examples of how the screening tools can be used for a particular development site are presented. The chapter concludes with a summary index that shows where more information on the design, cost and maintenance of a BMP option can be found elsewhere in the manual.

OBJECTIVES IN BMP PLANNING

Over the past two decades, a number of urban BMPs have been developed and refined to mitigate some of the adverse impacts associated with development activity. Experience has shown that each BMP option has both unique capabilities and persistent limitations. These, in turn, must be balanced with both the physical constraints imposed by the development site and the overall management objectives for the watershed. In practice, this balance is achieved through a negotiating process between the engineering consultant and the local planner. Typically, the engineering consultant is responsible for developing the initial BMP plan, and represents the interests of the developer. The planner reviews the plan to ensure that it conforms with local policies and design standards, and represents the interests of the community.

During the BMP review process, it is important to identify the ultimate objectives for managing runoff from the site. The objectives in nonpoint source pollution and stormwater management have gradually evolved over the years, and may vary considerably among jurisdictions. However, the local planner and engineering consultant often do recognize several common and general goals which should be incorporated into a BMP plan. At a minimum, the BMP plan jointly developed for a site should accomplish the following goals:

- Reproduce, as nearly as possible, the hydrological conditions in the stream prior to development.
- Provide a moderate level of removal for most urban pollutants.
- Be appropriate for the site, given physical constraints.
- Be reasonably cost-effective in comparison with other BMPs.
- Have an acceptable future maintenance burden.
- Have a neutral impact on the natural and human environment.

Reproduce Pre-development Hydrological Conditions

The historical concern in stormwater management has been to reduce the frequency and severity of downstream floods. In most areas, this goal is achieved by controlling the peak discharge computed for a specific design storm to pre-development levels. In reality, however, floods are but one of a series of hydrological changes brought about by watershed development. Other hydrological changes can have equally profound impacts on the quality of downstream aquatic habitat and/or the severity of streambank erosion. Some BMP options are capable of mitigating these impacts through artificial groundwater recharge or the control of small to intermediate storm events. Both the planner and the engineer should check the condition of stream channels downstream to determine if such options should be required.

Provide Moderate Pollutant Removal Capability

In recent years, BMP designs have been adapted to enhance pollutant removal during storms, and thereby, improve the quality of stormwater runoff delivered to receiving waters. BMPs differ markedly in the pollutant removal mechanisms they employ, and consequently, their performance in removing different pollutants can vary significantly. However, the engineer has some ability to enhance removal rates by increasing the volume of runoff effectively treated by the BMP, or by adding extra design features. The planner's responsibility is to provide specific guidance to the engineer on which urban pollutants are to be targeted for removal in the watershed.

Feasibility for the Site

A surprisingly high number of BMPs are constructed on sites for which they are not suitable. As a consequence, some BMPs are often plagued with chronic maintenance problems or nuisance conditions, and in extreme cases, may no longer function as designed. To prevent these sorts of problems from occurring, both the planner and engineer should clearly understand the physical restrictions associated with each BMP. In addition, the engineer should perform field tests to verify the physical condition of the site. Depending on the results, the engineer may have to modify the BMP plan or incorporate preventative design features.

Cost-effectiveness

The construction costs for different BMP options can vary substantially, even on similar sites. This is due to inherent differences in the methods and materials used for BMPs, as well as certain economies-of-scale. Since BMP costs are eventually passed on to the consumer, cost-minimization should be a priority for both the engineering consultant and the planner. Generally, the engineering consultant, who has a legitimate interest in developing the least cost plan for his or her client, will perform the needed cost analyses.

Acceptable Future Maintenance Burden

Like any other pollution control device, BMPs can only continue to be effective if they are regularly inspected and maintained. Maintenance tasks for most BMPs include both low cost routine tasks and more expensive non-routine tasks, such as rehabilitation or sediment removal. Maintenance costs for BMPs are significant. Over a twenty year interval they will often equal or exceed the initial construction cost. However, the cost and responsibility for maintenance is normally passed on to future residents or the public sector, and not the original developer.

Consequently, the planner must clearly vest responsibility for maintenance: How and when tasks will be performed, how it is to be financed, and who will inspect the BMP. In most cases, the maintenance burden of a BMP is ultimately rooted in the initial design and construction of the facility. Planners and engineers should work together in this phase to anticipate future maintenance problems at the site and develop designs that can alleviate them. If maintenance requirements are addressed during the design and construction phases, both the scope and cost of future maintenance activities can be sharply reduced.

Neutral Impact on the Environment

Urban BMPs nearly always represent a significant modification to both the natural environment and the adjacent community. As such, BMPs can either enhance or degrade the amenity values that both provide. Comparatively small investments in design, landscaping and maintenance can make a BMP an attractive feature of a community, or at least an unobtrusive one. Without such efforts, many BMPs become "dead space" in a development; that is, they appear unsightly or discordant, provide no habitat or recreational opportunities, and are plagued by nuisance problems. The importance of enhancing the amenity values of a BMP cannot be overemphasized, as resident perceptions about a BMP are generally formed by the amenities they do or do not provide. These perceptions, in turn, strongly influence their acceptance of and support for BMPs, which is critical if the same residents are expected to pay for maintenance.

BMP SCREENING TOOLS

To aid the planner or engineer in choosing the best BMP for a site, a series of screening tools have been developed to compare the capabilities and limitations of each BMP. The first screening tool can be used to identify which BMP options are physically feasible for the site (Figures 2.1 and 2.2). These help the designer to shorten the list of BMP options that need be considered at a site. The second screening tool (Figure 2.3) summarizes the stormwater benefits which are provided by each BMP option. The third screening tool (Figure 2.4) provides rapid guidance on the relative pollutant removal capability of BMPs for a number of urban pollutants of concern. Finally, the fourth screening tool (Figure 2.5) indicates what natural or human amenities, if any, can be provided by the BMP.

Assuming that one or more BMP option has been selected, final design can then begin. More detailed information on the specific design methods, maintenance requirements and cost estimating techniques for the BMP option can be found using the summary index (Table 2.1). The reader is also encouraged to refer to each individual BMP chapter during all phases of the design.

SCREENING BMPs BASED ON PHYSICAL SUITABILITY

The first step in choosing a BMP is to identify which BMPs are actually suitable for physical conditions of the site. The two most important physical factors to consider in this assessment are the total contributing watershed area, and the infiltration rate of the soils of the site. Most BMPs can only be applied within relatively narrow ranges of watershed area and soil types. Figure 2.1 shows these ranges in schematic fashion. Solid black bars indicate when these two factors do not pose a problem, and the absence of a bar denotes that the BMP probably should not be applied under the specified condition. In cases where the bar becomes narrow, the BMP may or may not be feasible for the site depending on local design standards, development intensity, or the expected level of future maintenance.

Figure 2.2 presents a matrix that shows whether a BMP is also subject to other physical restrictions. In these cases, a solid dot indicates that the factor is not normally a restriction, whereas an open dot suggests that it is a restriction. In most cases, these restrictions do not necessarily prevent the use of a BMP option, but may affect where a BMP is located on a site, or how it is designed. As a general rule, pond BMPs normally face fewer of these site restrictions than infiltration·BMPs.

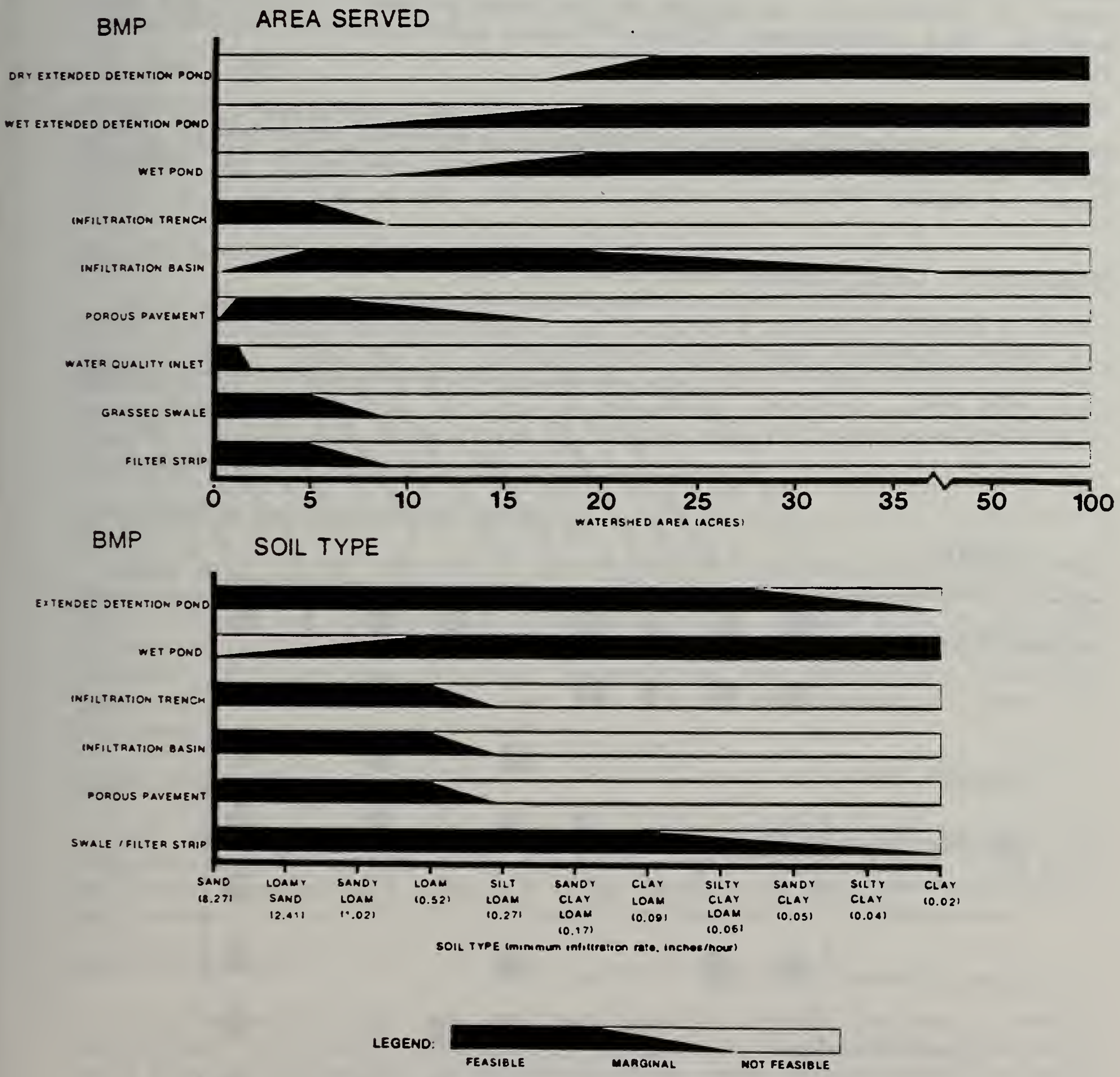
The nature of each of the physical factors outlined in these screening tools are described below.

Watershed Area Served

Pond BMPs normally require a significant contributing watershed area (greater than ten acres) to ensure proper operation. The lower range of suitability for ponds is set by the minimum orifice size for dry extended detention ponds, or the capacity to maintain water levels in wet ponds and wet extended detention ponds. By way of contrast, infiltration and vegetative BMPs are generally only applicable on sites less than ten acres, due to space, economic or flow velocity constraints.

It should be noted that the contributing area of a site does not always have to be fixed. By creatively using local topography and drainage, site area can be increased or decreased to better accommodate a particular BMP. For example, additional runoff generated away from the site (off-site runoff) can be routed to the BMP, thereby increasing total site area and making pond options more feasible. Conversely, various portions of the total runoff from a site can be routed to individual BMPs (decreasing site area, and making infiltration and vegetative BMPs more practical).

Figure 2.1: Watershed Area and Soil Permeability Restrictions for BMPs



Soil Type

The permeability of the soil underlying a BMP has a profound influence on its effectiveness. This is particularly true for infiltration BMPs, which cannot be applied on sites with soils that have infiltration rates (fc) less than 0.27 inches/hour, as defined by the least permeable layer in the soil profile. This excludes most "C" and "D" soils which cannot exfiltrate enough runoff through the subsoil.

Pond BMPs tolerate a much broader range of soil conditions. Extremely permeable sandy soils may make it difficult to maintain water levels in wet ponds, and clayey soils may cause standing water problems in dry extended detention ponds.

Figure 2.2: Other Common Restrictions on BMPs

BMP	SLOPE	HIGH WATER TABLE	CLOSE TO BEDROCK	PROXIMITY TO FOUNDATIONS	SPACE CONSUMPTION	MAXIMUM DEPTH	RESTRICTED LAND USES	HIGH SEDIMENT INPUT	THERMAL IMPACTS
EXTENDED DETENTION POND	●	●	◑	●	○	●	●	◑	●
WET POND	●	●	◑	●	○	○	●	◑	○
INFILTRATION TRENCH	○	○	○	○	●	○	●	○	●
INFILTRATION BASIN	◑	○	○	◑	◑	○	●	○	●
POROUS PAVEMENT	○	○	○	○	○	○	○	○	●
WATER QUALITY INLET	●	●	○	○	●	○	○	○	●
GRASSED SWALE	○	○	◑	◑	●	●	○	○	●
FILTER STRIP	◑	◑	◑	◑	●	●	◑	○	●

○ MAY PRECLUDE THE USE OF A BMP
◑ CAN BE OVERCOME w/ CAREFUL SITE DESIGN
● GENERALLY NOT A RESTRICTION

Slope

Steep slopes restrict the use of several BMPs. For example, porous pavement and grassed swales must be situated in sites with slopes of 5% or less. Also, infiltration trenches and filter strips are not practical when slopes exceed 20%.

High Water Table

The water table acts as an effective barrier to exfiltration and can sharply reduce the ability of an infiltration BMP to drain properly. If the height of the seasonally high water table extends to within four feet of the bottom of an infiltration BMP, the site is seldom considered suitable.

Close to Bedrock

The downward exfiltration of storm runoff is also impeded if the bedrock layer lies too close to the soil surface. As with a high water table, a close bedrock layer prevents an infiltration BMP from draining properly. Therefore, if the bedrock layer extends to within 2 to 4 feet of the bottom of an infiltration BMP, the site is not feasible. Similarly, pond BMPs are often not feasible if bedrock lies within the area that must be excavated to provide stormwater storage.

Proximity to Foundations and Wells

Since infiltration BMPs divert runoff back into the soil, some sites may experience problems with local seepage. This can be a real problem if the BMP is located too close to a building foundation. Another risk is that the runoff and pollutants diverted into the groundwater may contaminate water supplies. While relatively little research has been performed to evaluate this risk, it is advisable to keep infiltration BMPs located at least 100 feet away from drinking water wells.

Land Consumption

Some sites are so small or so intensively developed that no room is available for BMP options that consume a large amount of space. Pond BMPs and porous pavement both require a large surface area and a generous buffer, and consequently may not fit into extremely tight sites.

Maximum Depth

To preserve storage capacity and provide optimal pollutant removal conditions, infiltration BMPs must be designed to completely drain within 2 to 3 days after a storm. If the infiltration rates of the underlying soils are marginal, the depth of the infiltration facility may be limited. These restrictions vary depending on whether the facility is a trench, basin or porous pavement facility.

Wet ponds are also subject to a maximum depth limit as well. Extremely deep ponds (greater than 8 feet deep) may stratify during the summer and create low oxygen conditions near the bottom of the pond. This in turn, creates the potential for the release of pollutants from the sediments back into the water column.

Restricted Land Uses

Certain BMPs can only be applied to particular land uses, and are not broadly applicable for all development sites. Porous pavement, for example, can only be used for sites with parking lots not expected to receive heavy car or truck traffic. Similarly, grassed swales can only be used in conjunction with low density residential areas or roads.

High Sediment Input

Most BMPs are unable to handle the large loads of sediment eroded during the construction phase of development. Infiltration BMPs are particularly susceptible to rapid clogging and subsequent failure if significant sediment loads are allowed to enter the structure. As a general rule, these BMPs should not be installed until all of the land disturbed by construction in the contributing watershed is effectively stabilized. Contractors must often take unusual steps during the actual installation of the infiltration BMPs to prevent soil compaction or sediment contamination. Although sediment loads drop sharply after the construction phase, gradual clogging of infiltration BMPs can still occur, so many designs call for the use of a pre-treatment device to filter out sediment and other coarse particles before they reach the facility.

Pond BMPs can be used for sediment control during the construction phase of development, with proper conversion, clean-out and regrading. After the site is stabilized, significant amounts of pond storage capacity can still be lost due to the gradual accumulation of deposited sediments. After 5 to 20 years, the sediment deposits are large enough to impair the function of a pond, and must be removed. The cost and scope of sediment removal can be reduced by preventative design, extra storage and/or sediment forebays.

Thermal Enhancement

Shallow marshes and wet ponds warm up rapidly during the summer months. Under certain circumstances, runoff leaving these BMPs can be 5 to 10 degrees warmer than the runoff entering the structure. Such warm water release can be a lethal thermal shock to aquatic organisms that are adapted to coldwater conditions. Thus, the use of wet ponds and shallow marshes should be avoided in watersheds with sensitive coldwater streams.

SCREENING BMPs BASED ON STORMWATER BENEFITS PROVIDED

The objective of stormwater management is to attempt to reproduce the pre-development hydrology of the site. As noted earlier, this can be done through a combination of peak discharge control, volume control, groundwater recharge and streambank erosion control. Figure 2.3 shows the extent to which common BMP designs provide these benefits. A solid dot indicates that the BMP normally provides the benefit; an open dot indicates that it does not; and a half dot suggests that the benefit might be provided in certain sites or with special design modifications. As can be seen, very few BMP options can achieve the full spectrum of desirable stormwater benefits. This is because a different flow condition and/or frequency must be controlled to provide each benefit. As an example, the designer needs to control very large, infrequent storms to attain peak discharge control, yet must concentrate on much smaller and more frequent storms to provide groundwater recharge.

The design variations for infiltration BMPs shown in Figure 2.3 deserve some additional explanation. The term "exfiltration" refers to the amount of runoff that is effectively infiltrated through the soil profile. Full exfiltration occurs when all of the runoff delivered to an infiltration BMP is completely exfiltrated back into the soil. As one might imagine, full exfiltration BMPs need to be very large in volume. Partial exfiltration BMPs only divert a fixed volume of runoff into the soil (the remaining runoff is conveyed through the BMP, but may be detained long enough to provide some peak discharge control). In water quality exfiltration BMPs, a small, fixed runoff volume is diverted into the soil. The remaining runoff is conveyed away, and is not detained long enough to provide any peak discharge control.

Peak Discharge Control

As shown in Figure 2.3, peak discharge control is often required for one or more design storms under local regulations. The most common design storm used is the 2 year storm, which is a flood that occurs, on average, every two years. In natural watersheds, the two year storm produces a flood that fills a stream to the top of its banks (i.e., the bankfull flood). Some jurisdictions also require control of the 10 or 100 year design storms, particularly if there is unprotected development further downstream on the floodplain. Even if a BMP does not control these larger design storms, they must still be designed to safely pass them through (e.g., using an emergency spillway or an overflow pipe).

Peak discharge control is accomplished in pond BMPs by temporarily detaining a large portion of the runoff volume for the design storm, and then releasing it at the lower pre-development rate. This is done by using a vertical riser with a control orifice or weir. A single pond can control a series of design storms by using a series of orifices and weirs at progressively higher elevations. In general, pond BMPs are an excellent means of providing peak discharge control.

Infiltration BMPs have a more limited capacity to control peak discharges. Full exfiltration systems are normally only capable of controlling peak discharges for the 2 year storm (and in rare cases, the 10 year storm). Most partial exfiltration systems can control the 2 and 10 year storm, and pass the 100 year storm. Water quality exfiltration systems, water quality inlets, swales, and filter strips normally have little or no capacity to control peak discharges.

Volume Control

Infiltration BMPs can help to reduce the increased runoff volumes generated from small and intermediate storms, since they divert a significant fraction of storm runoff volume back into the soil. Pond BMPs, on the other hand, are ineffective in reducing runoff volume. Ponds only detain or retain runoff for a short period of time before releasing it downstream.

Figure 2.3: Comparative Stormwater Benefits Provided by Urban BMPs

BMP	PEAK DISCHARGE CONTROL					
	2 YEAR STORM	10 YEAR STORM	100 YEAR STORM	VOLUME CONTROL	GROUNDWATER RECHARGE	STREAMBANK EROSION CONTROL
EXTENDED DETENTION						
DRY	●	●	●	○	○	●
DRY w/ MARSH	●	●	●	◑	○	●
WET	●	●	●	○	○	●
WET POND	●	●	●	◑	○	○
INFILTRATION TRENCH						
FULL EXFILTRATION	●	◑	○	●	●	●
PARTIAL EXFILTRATION	●	●	○	●	●	●
WATER QUALITY TRENCH	○	○	○	●	●	●
INFILTRATION BASIN						
FULL EXFILTRATION	●	◑	○	●	●	●
INFILTRATION/DETENTION	●	●	●	●	●	◑
OFF-LINE BASIN	○	○	○	●	●	◑
POROUS PAVEMENT						
FULL EXFILTRATION	●	◑	○	●	●	●
PARTIAL EXFILTRATION	●	●	◑	●	●	◑
WATER QUALITY	○	○	○	●	●	◑
WATER QUALITY INLET	○	○	○	○	○	○
GRASSED SWALE	◑	○	○	◑	◑	○
FILTER STRIP	◑	○	○	◑	◑	○

○ SELDOM OR NEVER PROVIDED

◑ SOMETIMES PROVIDED w/ CAREFUL DESIGN

● USUALLY PROVIDED

Groundwater Recharge

Infiltration BMPs are an excellent means of providing for groundwater recharge, which is often lost as a consequence of watershed development. "Natural" levels of groundwater recharge can be duplicated by diverting a significant fraction of the runoff from frequent small and moderate storms back into the soils. Most exfiltration designs recharge the groundwater sufficiently to sustain normal low flows in headwater streams during the critical summer months. Vegetative BMPs, such as grassed swales and filter strips have a more limited capability, and pond BMPs generally have little or none.

Streambank Erosion Control

All BMPs that control peak discharges for the 2 year storm provide some degree of streambank erosion control. However, the 2 year storm creates an erosive condition in natural channels (i.e., a bankfull discharge). To adequately protect downstream channels, it is necessary to control both the post-development increase in the 2 year bankfull flood and the increased frequency with which it occurs. This normally entails the control of storm events of intermediate size (less than the 2 year storm and greater than the mean storm). Some preliminary design suggestions for minimizing the increased frequency of bankfull flooding are provided in Appendix B. Based on this analysis, it appears that extended detention ponds and some infiltration BMPs can effectively reduce the frequency with which bankfull flooding occurs, if sized properly. Wet ponds (without extended detention), vegetative BMPs, and water quality inlets show little capability in this regard.

SCREENING BMPs BASED ON POLLUTANT REMOVAL BENEFITS

The pollutant removal capability of a BMP is primarily governed by three interrelated factors: 1) the removal mechanisms used, 2) the fraction of the annual runoff volume that is effectively treated, and 3) the nature of the urban pollutant being removed. The designer has a limited ability to control the first two factors, but has no influence on the third.

Figure 2.4 illustrates the comparative pollutant removal capabilities of BMP options. The removal rates shown are inferred from field performance monitoring, laboratory experiments, modeling analyses and theoretical considerations. Due to the inherent uncertainties involved, removal rates are expressed in 20 percent increments. A removal rate has been estimated for several design variations of each BMP. The design variations for each BMP are arrayed in order of increasing fractions of annual runoff volume treated.

As noted earlier, the nature of the pollutant being removed often sets an upper limit on the potential removal rate that can be achieved. From an operational standpoint, pollutants can be said to exist in either particulate or soluble forms, or more commonly, as a mix of both forms (MWCOG, 1987). Particulate pollutants, such as sediment and lead, are relatively easy to remove by common BMP removal mechanisms, including settling and filtering. Soluble pollutants, such as nitrate, phosphate, and some trace metals, are much more difficult to remove. Settling and filtering removal mechanisms have little or no effect, and biological mechanisms, such as uptake by bacteria, algae, rooted aquatic plants or terrestrial vegetation, must be used.

The importance of pollutant form can clearly be seen in Figure 2.4. Most BMPs can achieve an extremely high removal rate for suspended sediment and trace metals that exist largely in particulate forms. Much lower removal rates are generally obtained for total phosphorus, oxygen-demanding materials and total nitrogen, since they typically exist as a mix of particulate and soluble forms.

The following sections summarize the pollutant removal capability of BMPs, with an emphasis on their major removal mechanisms, and design enhancements which can be used to improve their performance.

Extended Detention Ponds

Dry extended detention ponds rely primarily on settling to remove pollutants. Depending on how much and how long runoff is detained, it is possible to achieve moderate or high removal rates for particulate pollutants that are relatively easy to settle. However, removal rates for most soluble pollutants are quite low for dry extended detention ponds, although it is possible to enhance rates by incorporating biological removal mechanisms into the design of the pond (e.g., by establishing a shallow marsh in the bottom stage of a dry extended detention pond, or by using extended detention in combination with a wet pond).

Wet Ponds

Wet ponds have a moderate to high capability of removing most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff produced from the surrounding watershed. Wet ponds utilize both settling and biological uptake, and are capable of removing both particulate and soluble pollutants. In addition to increasing the volume of the permanent pool, wet pond removal rates can be enhanced by establishing marshes around the perimeter, and by adjusting the geometry of the pond.

Infiltration Practices (trenches, basins, porous pavement)

From a pollutant removal standpoint, infiltration trenches, basins, and porous pavement behave in a similar manner, and can be treated as a group. Infiltration practices filter runoff through the soil layer, where a number of physical, chemical and biological removal processes occur. Infiltration practices have a moderate to high removal capability for both particulate and soluble urban pollutants, depending how much of the annual runoff volume is effectively exfiltrated through the soil layer. Removal rates can be further enhanced by increasing the surface area reserved for exfiltration and adjusting the geometry of the practice to achieve a draining time of less than 3 days. It should be noted that infiltration practices should not be relied on to achieve high levels of particulate pollutant removal (particularly sediments), since these particles can rapidly clog the device. Rather, particulate pollutants should be removed before they enter the structure by means of a filter strip, sediment trap or other pretreatment device.

Figure 2.4: Comparative Pollutant Removal Of Urban BMP Designs

BMP/design	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	TOTAL NITROGEN	OXYGEN DEMAND	TRACE METALS	BACTERIA	OVERALL REMOVAL CAPABILITY
EXTENDED DETENTION POND							
DESIGN 1	◕	◔	◔	◔	◑	⊗	MODERATE
DESIGN 2	●	◑	◔	◑	◕	⊗	MODERATE
DESIGN 3	●	◕	◑	◑	◕	⊗	HIGH
WET POND							
DESIGN 4	◕	◑	◔	◔	◔	⊗	MODERATE
DESIGN 5	◕	◑	◔	◔	◕	⊗	MODERATE
DESIGN 6	●	◕	◑	◑	◕	⊗	HIGH
INFILTRATION TRENCH							
DESIGN 7	◕	◑	◑	◕	◕	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
INFILTRATION BASIN							
DESIGN 7	◕	◑	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
POROUS PAVEMENT							
DESIGN 7	◑	◕	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◕	◕	◕	●	●	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
WATER QUALITY INLET							
DESIGN 10	○	⊗	⊗	⊗	⊗	⊗	LOW
FILTER STRIP							
DESIGN 11	◔	○	○	○	◔	⊗	LOW
DESIGN 12	●	◑	◑	◕	●	⊗	MODERATE
GRASSED SWALE							
DESIGN 13	○	○	○	○	○	⊗	LOW
DESIGN 14	◔	◔	◔	◔	○	⊗	LOW

KEY:

○ 0 TO 20% REMOVAL
◔ 20 TO 40% REMOVAL
◑ 40 TO 60% REMOVAL
◕ 60 TO 80% REMOVAL
● 80 TO 100% REMOVAL
⊗ INSUFFICIENT KNOWLEDGE

Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 1.0 inch, detained 24 hours.
Design 3: As in Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 0.5 inch storage per impervious acre.
Design 5: Permanent pool equal to 2.5 (Vr); where Vr=mean storm runoff.
Design 6: Permanent pool equal to 4.0 (Vr); approx. 2 weeks retention.
Design 7: Facility exfiltrates first-flush; 0.5 inch runoff/imper. acre.
Design 8: Facility exfiltrates one inch runoff volume per imper. acre.
Design 9: Facility exfiltrates all runoff, up to the 2 year design storm.
Design 10: 400 cubic feet wet storage per impervious acre.
Design 11: 20 foot wide turf strip.
Design 12: 100 foot wide forested strip, with level spreader.
Design 13: High slope swales, with no check dams.
Design 14: Low gradient swales with check dams.

Water Quality Inlets

Current designs of water quality inlets appear to have low to moderate removal rates for particulate pollutants, and low to zero rates for soluble pollutants. Water quality inlets rely primarily on settling for removal, and given their small storage capacity and brief residence times, it is likely that only coarse grit, sand, and some silts will be trapped. Inlets do show some promise in removing hydrocarbons, such as oil, gas and grease, from runoff. Due to resuspension problems, however, pollutant removal can only be attained in water quality inlets if they are cleaned regularly.

Filter Strips

Filter strips have a low to moderate capability of removing pollutants in urban runoff, and exhibit higher removal rates for particulate rather than soluble pollutants. Removal mechanisms include filtering (through vegetation and/or soil), settling/deposition and uptake by vegetation. Forested buffer strips appear to have a higher removal capability than grass buffer strips. However, length, slope and soil permeability are critical factors which influence the effectiveness of any strip. Another practical design problem is how to prevent runoff from concentrating and thereby "short-circuiting" the strip. Special design modifications and regular maintenance are needed to provide optimal removal rates in the field.

Grassed Swales

Grassed swales have a low capability of removing urban pollutants, except under site conditions which are unusual in the Washington metropolitan area (e.g., extremely gentle slopes, permeable and uncompacted soils, installation of check dams and maintenance of a dense grass turf). If constructed under these conditions, pollutants can be removed through the filtering action of the grass, by deposition in low velocity areas, and by exfiltration through the soil layer. Moderate removal of particulate pollutants, and low removal of soluble pollutants can be expected under these optimal conditions.

SCREENING BMPs FOR ENVIRONMENTAL AMENITIES

Figure 2.5 is a screening tool that shows the environmental and human amenities which can be provided by a particular BMP. In most cases, these amenities are not automatically provided when a BMP is built. Rather, they are a result of thoughtful design, regular maintenance, and creative landscape planting. In this matrix, a solid dot indicates that there is a strong potential for a BMP to provide the amenity; an open dot indicates the BMP has little or no potential; and a half dots suggests that a BMP might provide the amenity with some design modifications or as a result of unusual site conditions.

The first five headings in Figure 2.5 refer to amenities related to the improvement of the natural environment, while the last five headings pertain to amenities which are provided to the adjacent community. As might be expected, community amenities are quite subjective, and often adjacent residents hold widely divergent opinions as to their value. However, based on opinion surveys and less formal surveys of complaints to public works officials, some generalities have been made.

Figure 2.5: Environmental and Community Amenities Provided by BMPs

BMP	LOW FLOW MAINTENANCE	STREAMBANK EROSION CONTROL	AQUATIC HABITAT CREATION	WILDLIFE HABITAT CREATION	NO THERMAL ENHANCEMENT	LANDSCAPE ENHANCEMENT	RECREATIONAL BENEFITS	HAZARD REDUCTION	AESTHETICS	COMMUNITY ACCEPTANCE
DRY EXTENDED DETENTION	○	●	◑	●	●	◑	◑	◑	◑	◑
TENDED DETENTION w/ MARSH	○	●	●	●	○	◑	○	◑	◑	◑
WET EXTENDED DETENTION	○	●	●	●	○	●	●	◑	◑	●
WET POND	○	○	●	●	○	●	●	◑	◑	●
INFILTRATION TRENCH	●	◑	○	○	●	○	○	●	○	●
INFILTRATION BASIN	●	◑	○	●	●	◑	◑	●	○	◑
POROUS PAVEMENT	●	◑	○	○	●	○	○	●	○	●
WATER QUALITY INLET	○	○	○	○	●	○	○	●	○	●
GRASSED SWALE	◑	○	○	◑	●	◑	○	●	◑	●
FILTER STRIP	◑	○	○	●	●	◑	○	●	◑	●
SHALLOW MARSH	○	○	●	●	○	◑	○	◑	◑	◑

○ SELDOM PROVIDED

◑ SOMETIMES PROVIDED (w/ Design Modifications)

● USUALLY PROVIDED

Low Flow Maintenance

Downstream aquatic life can be jeopardized when the natural low flow levels experienced during the summer months decline even further because of reduced infiltration in urbanized watersheds. Infiltration BMPs contribute significantly to groundwater recharge and appear to be capable of sustaining low flows during the critical summer months if widely applied in a watershed. Vegetative BMPs, such as swales and filter strips, appear to have modest potential in this regard, and pond BMPs have little effect in maintaining low flows.

Streambank Erosion Control

Streambank erosion not only contributes large sediment loads to receiving waters, but also has an adverse impact on the habitat quality for downstream aquatic life. Some BMPs, such as extended detention ponds and full exfiltration BMPs, can control erosive stormflows enough to keep downstream channels and banks relatively stable, whereas most other BMPs have only marginal capabilities.

Aquatic Habitat Creation

Some BMP options are attractive in that they can create wetland or open water areas utilized by waterfowl, marsh birds, and other wildlife. Shallow marshes and wet ponds are particularly well suited for this role, if relatively small investments are made in landscaping design and plant selection. "Volunteer" wetland plants may also colonize these BMPs (and poorly drained extended detention ponds) without intentional planting efforts, but may not provide high quality habitat. Tips for enhancing aquatic habitat are presented in the Chapter 4 and the Basin Landscaping Guide (Chapter 9).

Wildlife Habitat Creation

BMPs with generous buffers (wet ponds, extended detention ponds, infiltration basins and filter strips) present good opportunities for creating terrestrial wildlife habitat. The buffer areas (and sometimes the basin floors) can be managed as wet meadows, thus reducing mowing costs for the facility. Relatively diverse biological communities can be further enhanced through judicious planting of trees, shrubs and grasses that provide food and cover for wildlife (see Chapter 9). These communities have added value because of the general scarcity of wildlife habitat in urbanized areas.

No Thermal Enhancement

As noted earlier, wet ponds can be detrimental in some watersheds as they heat water passing through the structure during the summer months. Their use is often restricted in watersheds that contain sensitive coldwater fisheries, such as those that support native trout populations.

Landscape Enhancement

Few BMPs will be an attractive feature of a community unless serious efforts are directed toward natural grading, landscaping and regular maintenance. If properly designed, pond options probably have the most potential to enhance the urban landscape. Wet ponds are frequently used to create a waterfront effect in residential developments, and may actually increase the value of adjacent property. Vegetative BMPs have a less dramatic effect on landscape values, and most infiltration BMPs and dry extended detention ponds have a neutral or negative effect.

Recreational Benefits

With the exception of large wet ponds, few BMPs provide active recreational opportunities (e.g., fishing, swimming, or skating). In fact most jurisdictions generally do not encourage such activities, as they may invite vandalism or liability problems. However, if properly landscaped, pond BMP options can provide passive recreation opportunities for adjacent residents, such as walking, birdwatching, or nature enjoyment, particularly when combined with bike or jogging paths, picnic areas, and tot-lots situated in nearby open space. In rare instances, the floors of extended detention ponds can even be used for ballfields and play areas.

Hazard Reduction

Careful design of pond BMPs is needed to reduce potential safety hazards. Plans should be analyzed to eliminate obvious hazards, such as steep side-slopes, deep water, sudden drop-offs from the shore, or dangerous outlet/pipe configurations. Most infiltration BMPs entail little if any safety risks, and some (porous pavement) are thought to reduce certain traffic safety problems.

Aesthetic Value

As shown in Figure 2.5, most pond options have the potential to be either an attractive or an unattractive feature of a community, depending on the attention paid to their design, landscaping ,and maintenance. Artificial contours should be avoided, and control structures (risers, low flow channels, outlets and riprap) should be concealed in the embankment, or by vegetation where feasible. Infiltration BMPs generally have little potential to be attractive, but can at least be designed to be unobtrusive.

Community Acceptance

Surveys of resident perceptions about adjacent BMPs have revealed that most BMPs are acceptable if regular cosmetic maintenance is performed. Residents often indicate a preference for wet ponds over dry ponds. Their response to infiltration BMPs is not well documented. Residents' primary concerns often center around perceived nuisance conditions (algae blooms, odors, mosquitos, weeds, trash, turbidity, etc.), most of which are temporary conditions which should seldom occur if the BMP is properly designed and maintained.

HOW TO USE THE SCREENING TOOLS

The following examples provide illustrations of how the screening tools provided in this Chapter are best used.

EXAMPLE 2-1:USE OF THE SCREENING TOOLS

A developer has a 5 acre parcel which will be converted into an office complex and parking lot. The site has low slopes and permeable, sandy loam soils. The management objectives for the site are; 1) 2 year peak discharge control, 2) groundwater recharge, and 3) moderate to high removal of all urban pollutants.

Step 1. Using Figure 2.1 the following BMPs are suitable, given the area and soil characteristics of the site:

1. Infiltration Trench
2. Infiltration Basin
3. Porous Pavement
4. Grassed Swale
5. Filter Strip

After checking the other site restrictions contained in Figure 2.2, and the accompanying text, it is apparent that grassed swales and filter strips are not appropriate, given the proposed high land-use intensity. The remaining BMP options appear feasible, but must have some kind of pretreatment device to protect them from high sediment inputs.

Step 2. Full or partial exfiltration designs of the infiltration BMP options can provide the desired 2 year peak discharge control and groundwater recharge benefits:

1. Infiltration trench
2. Infiltration basin
3. Porous pavement

Step 3. If the infiltration BMPs are sized according to design rules 8 or 9, high levels of pollutant removal can be expected for all of the remaining options (see Figure 2.4).

Step 4. All of the remaining BMP options provide a similar level of environmental amenities (Figure 2.5).

Step 5. A final BMP option can now be selected on the basis of costs or maintenance requirements. Estimation of both can be found elsewhere in the text using Table 2.1.

EXAMPLE 2-2:USE OF THE SCREENING TOOLS

A developer is planning to build a residential subdivision on a 40 acre parcel of land, with moderate slopes (5%) and sandy clay loam soils. Local ordinances require peak discharge control for the 2 and 10 year design storm. In addition, the planning review agency has specified that the BMP should provide a high level of streambank erosion control, and provide a moderate to high level of nutrient removal. Because of the intended character of the residential area, the developer would like the BMP to provide environmental amenities. Using the screening tools, identify the BMP option(s) which are physically suitable for the site, and determine whether they can provide the desired benefits.

Step 1. From Figure 2.1, it is evident that most infiltration BMPs are not feasible because of watershed area and soil permeability restrictions. The remaining options are:

1. Dry extended detention pond
2. Wet extended detention pond
3. Wet pond

Based on Figure 2.2, which shows other common site restrictions for BMPs, it appears that no other insurmountable limitations exist for the use of the BMPs listed above.

Step 2. Using Figure 2.3, it is evident that all these BMPs can control peak discharges from the 2 and 10 year storm. However, only dry and wet extended detention ponds can provide the desired level of streambank erosion control.

Step 3. From a nutrient removal standpoint, dry extended detention (design 3, with marsh) and wet extended detention (design 6) both have the potential to provide high levels of removal (Figure 2.4).

Step 4. As shown in Figure 2.5, both dry extended detention with marsh, and wet extended detention ponds provide several natural environmental amenities, with proper landscaping and maintenance. These include streambank erosion control, and wildlife and aquatic habitat creation. From the standpoint of community amenities, wet extended detention appears to be preferable, as it gets higher marks for landscaping, recreation, and resident acceptance.

Based on the screening tool, and the stated management objectives for the site, the most appropriate BMP would be a wet extended detention pond. Methods for estimating construction costs and maintenance requirements for the BMP can be found by referring to the appropriate section of this manual, as outlined in Table 2.1.

FINAL DESIGN CONSIDERATIONS

Once a BMP has been selected for the site, more detailed design of the facility can begin. As noted earlier, the designer should consider a number of design features that can enhance pollutant removal, reduce maintenance needs and costs, reduce construction costs, and provide desired environmental and community amenities. Table 2.1 provides a summary index on where such design information can be found within this manual.

Tips for Enhancing Pollutant Removal

Each BMP chapter in this manual contains a section that provides a series of design tips to maximize the pollutant removal capability of a BMP. These guidelines include: ways of adjusting the size and geometry of a BMP to create ideal removal conditions; how vegetation can be effectively used to promote biological removal; how optimum detention/draining times can be achieved; and other means of achieving high pollutant removal requirements.

Table 2.1: Summary Index for BMP Design

	TIPS FOR ENHANCING POLLUTANT REMOVAL	MAINTENANCE REQUIREMENTS FOR THE BMP	TIPS FOR REDUCING MAINTENANCE NEEDS	PROJECTING BMP CONSTRUCTION COSTS	DESIGN VARIATIONS FOR THE BMP	DETAILED DESIGN METHODS FOR THE BMP	DESIGN SUMMARIES
EXTENDED DETENTION	3.14	3.21	3.24	3.20	3.2	3.26	3.27
WET PONDS	4.4	4.13	4.15	4.12	4.4	4.20	4.21
INFILTRATION TRENCH	5.15	5.21	5.23	5.18	5.2	5.25	5.26
INFILTRATION BASIN	6.9	6.14	6.15	6.13	6.2	6.17	6.18
POROUS PAVEMENT	7.10	7.17	7.20	7.13	7.2	7.22	7.23
WATER QUALITY INLET	8.5	8.8	8.8	8.8	8.2	8.8	8.9
GRASSED SWALE	9.3	9.6	9.6	9.6	–	9.10	–
FILTER STRIP	9.7	9.9	9.9	9.9	–	9.10	–
SHALLOW MARSH	–	–	–	9.5	–	9.18	–

Common Maintenance Requirements

Both the regular and non-routine maintenance requirements for each BMP are described in detail elsewhere in this manual. Where data is available, estimates of the costs associated with maintenance are provided, as are inspection schedules and methods. Where construction methods are critical to the successful operation of the BMP, recent specifications on materials and workmanship are also provided.

Tips For Reducing Maintenance Needs

Engineers should make maintenance reduction a major element of every BMP design. A significant amount of future maintenance activities and costs can be eliminated through preventative design. Each BMP chapter includes a series of tips which should be carefully reviewed. These include suggestions on how to reduce maintenance needs by providing access, using long-lasting construction materials, trapping sediment inputs, creative use of the geometry of the BMP to make routine maintenance easier, providing backup drainage systems, and proper stabilization of erosion-prone areas.

Projecting BMP Construction Costs

Each BMP chapter presents a method for computing a rapid planning estimate of the construction costs of a BMP. Unit costs for major construction components are provided for infiltration and pond BMPs (see Table 7.4). Cost equations are also provided for a number of BMPs. The cost-effectiveness of each BMP, in relation to watershed size, development intensity, and other BMP options, is also discussed (see also MWCOG, 1983a; Wiegand et al, 1986).

Design Variations

Each BMP chapter begins with a section that describes several variations in the basic design of a BMP. These designs, drawn from applications around the Washington, D.C. area, illustrate innovative ways to fit a BMP into a particular development site and combine BMPs together to improve performance or minimize maintenance needs.

Design Methods

This manual does not provide step-by-step methods for the hydrological design of BMPs, nor does it give specific models or equations that can be used to accurately determine the necessary storage requirements, geometry and configuration of a BMP at a particular site. These technical aids, used for the final BMP design, are provided by reference at the end of each chapter.

Design Summary

Each chapter concludes with a brief design summary that highlights some of the recommended BMP design features that should be included in every site plan. Both the engineering consultant and the site-plan reviewer can use these summaries as a checklist to ensure that the BMP plan for the site will be effective.

STANDARD

FOREST LAND EROSION CONTROL (Acre)

Definition

Application of one or more erosion control measures on forest land. Erosion control includes the uses of conservation plants, cultural practices, and erosion control structures on disturbed forest land for the control of sheet and rill erosion, gully formation, and mass soil movement.

Scope

This standard gives guidelines for installing, operating and maintaining forest land erosion control systems. This practice does not apply to stabilizing gullies, streambanks or other critical areas not outlined in this standard.

Purpose

To protect the resource base by reducing erosion and sedimentation, and enhancing water quality on forest land where disturbances are caused by silvicultural or other activities.

Conditions Where Practice Applies

This standard applies to all disturbed forest land areas including logging roads, skid roads, and loading areas; buffer or filter strips; slash disposal areas; site preparation; and burned and overgrazed areas.

Planning Considerations for Water Quantity and Quality

QUANTITY

1. Effects on the water budget, especially on runoff and ground water recharge.

2. Effects on the volume of downstream flow on environmental, social and economic values.

3. Effects on downstream flows or aquifers that could affect other water uses or users.

QUALITY

1. Effects on erosion and the movement of sediment and soluble and sediment-attached substances that would be carried by runoff.

2. Effects on the movement of dissolved solids to ground water.

3. Effects on wetlands or water-related wildlife habitats.

4. Effects on visual quality of water resources.

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I. Planning Considerations

During initial planning, inform landowners of applicable laws which relate to harvesting activities, wetlands, surface waters, and fish and wildlife habitat.

Proper location of roads, skid trails, and landings is the most cost effective means of controlling erosion. Use topographic maps and aerial photos to help plan access systems. Locate control points such as stream crossings, steep slopes, wetlands, filter strips, buffer strips, and property boundaries on topographic maps. Use a scale or draftsman's dividers to identify tentative road locations which have acceptable grades. Field check tentative road and trail locations and make adjustments prior to flagging a final location.

Whenever possible, help landowners plan erosion control systems prior to harvesting when the forest cutting plan is being developed in compliance with the Massachusetts Forest Cutting Practices Act (M.G.L. Chapter 132, Sections 40 through 46).

Use slash to reduce the velocity of runoff water, trap sediment, surface skid trails and roads, and mulch areas subject to erosion.

As appropriate exclude livestock and vehicles from areas being treated.

II. State Requirements

Requirements of the Massachusetts Forest Cutting Practices Act which must be considered are:

- Wetlands (as defined in M.G.L. Chapter 131, Section 40) and steep slopes (60 percent or greater) must be identified prior to harvesting and special forms filed with the Forest Cutting Plan.

- Wetlands are not to be harvested (operated) except when the ground is frozen, dry, or otherwise stable.

- On steep slopes of 30 percent or greater, constructed cut and fill skid roads are required by law. The Forest Cutting Practices Act also prohibits skidders from operating on slopes of 60 percent or greater.

- Filter strips of at least 50 feet are required along all water bodies and wetlands.

- Buffer strips are required along edges of maintained ways and water bodies. Buffer strips of 100 feet are required along all paved publicly maintained ways, designated scenic ponds, rivers of 25 feet or more in width, and around ponds and lakes of 10 or more acres. Elsewhere, 50 foot buffer strips are required, i.e., unpaved ways, streams less than 25 feet wide, and bodies of water less than 10 acres.

- No more than 50 percent of the basal area may be cut in a filter or buffer strip at any one time. A waiting period of 3 years is required between cuts in these areas.

- Heavy equipment is not to enter filter strips except to cross streams, travel existing roads or to reduce environmental damage as approved in the Cutting Plan.

- Gravel or mulch is required on all roads from landings to public highways.

III. Seeding and Design Criteria for Disturbed Areas

Disturbed areas such as Roads, Skid Trails, Landings or Yards, Firebreaks, and Burned Areas.

Surface water is adequately controlled, see Field Office Technical Guide, Section III.

1. Permanent Vegetative Cover

Establish permanent vegetation where:

- conditions are less favorable for invasion of native vegetation, i.e., large areas, infertile soil, droughty sites

- long term soil erosion control is needed

- maintenance of a right-of-way is desired and/or

- improved wildlife habitat (food or cover) is desired.

Select a seeding mixture from Table 1.

Lime and fertilize to soil test specifications or apply 2 tons/ac. ground agricultural limestone (high magnesium) and fertilize with 500-800 lbs. of 10-20-20 or the equivalent to be consistent with C.A.T. specification.

a. With Seedbed Preparation
Where feasible, prepare a seedbed by grading, removing debris and scarifing with a bog harrow, toothed dozer blade, heavy chains, brush, etc.

Table 1. Seed Mixtures for Permanent Seedings 1/

Area/Purpose	Drainage Class	Soil pH	Amount of Shade	Appropriate Mixtures 2/ (lbs./ac.)	
Winter Roads & Landing/Wildlife	Poorly	5.0-7.5	Moderate to None	Reed Canarygrass	20
				Birdsfoot Trefoil 3/	10
				Redtop	2
Road/Trail Landing/Burned Over	Excessively to Somewhat Poorly	4.5-7.5	Heavy to None	Creeping Red Fescue	20
				Tall Fescue	20
				Redtop	2
Road/Trail/Landing Burned Over/ Brush Control	Excessively to Somewhat Poorly	5.5-7.5	Moderate to None	Flatpea	30
				Tall Fescue	20
				Redtop	2
Road/Landing Wildlife	Well to Somewhat Poorly	5.0-7.5	Moderate to None	Creeping Red Fescue	20
				Birdsfoot Trefoil 3/	8
				Redtop	2
Road/Landing Wildlife	Well and Moderately Well	5.5-7.5	Moderate to None	Crownvetch 3/	15
				Tall Fescue	15
				Creeping Red Fescue	10
				Redtop	2

1/ Seeding dates. Seed disturbed areas as soon as possible. Seed as early in the spring as the ground can be worked and in fall until the ground freezes or snow falls. The seeding rates are expressed in rates of pure live seed. Pure live seed, abbreviated PLS, is a method of defining the planting quality of seeds. To calculate PLS, the percentage of pure seed is multiplied by the percentage of germination, and the product is divided by 100. Thus: (85 percent pure seed x 72 percent germination)/100 = 61 percent PLS. To determine how much actual seed to plant, divide the percentage PLS into 100. Thus, in our example, 100/61 = 1.63. Hence 1.6 pounds of seed with a purity of 72 percent and a germination of 85 percent would need to be planted for each pound specified in the desired seed mixture. Recommended varieties are listed at the end of the section.

2/ Include 10-20 lbs./ac. of winter rye when seeding after September 15. On critical areas or droughty sites, apply hay or straw mulch at the rate of 90 lbs./1000 sq. ft. Anchor mulch on steep slopes or where subjected to concentrated flow.

3/ Innoculate with correct innoculant immediately prior to planting. Use four times the recommended rate when hydroseeding.

b. Without Seedbed Preparation
Seedings without site preparation may be prescribed where a reasonable amount of bare soil exists and seedbed preparation is not feasible or desirable.

2. Temporary Cover
Establish temporary vegetation where:

- conditions are favorable for rapid invasion of native vegetation,
- leaf litter eventually will provide adequate soil erosion protection, or
- permanent vegetation will be established after harvesting or construction is complete.

Select a seeding mixture from Table 2.

If soil conditions are suitable, temporary cover may be seeded without lime and fertilizer on sites where access is difficult, i.e., steep slopes, muddy conditions or where labor and machinery are limited.

3. Maintenance of Vegetation
Check seedings periodically to ensure that adequate cover is established. If necessary to prevent erosion, reseed bare spots, top dress with lime and fertilizer, or mulch.

IV. Filter Strips

To control sediment movement maintain filter strips of undisturbed vegetation along streams, rivers, lakes, ponds, and wetland borders. Locate roads and trails outside of filter strips except for approaches to crossings.

Table 2. Temporary Seeding Mixtures 1/

Area/Purpose	Soil pH	Amount of Shade	Seeding Mixtures 2/ (lbs./ac.)	
Road/Trail/Landing Landing/Burned Area	4.5-7.5	Heavy to None	Creeping Red Fescue Redtop	40 2
Road/Trail Landing	5.5-7.5	Heavy to None	Annual Ryegrass	40
Road/Trail Landing Wildlife	5.5-7.5	Moderate to None	Winter Rye	112 (2 bu.)

1/ For Excessively Well to Somewhat Poorly Drained Soils. Seed disturbed areas as soon as possible. Seed as early in the spring as the ground can be worked and in fall until the ground freezes or snow falls.

2/ On critical areas or droughty sites, apply hay or straw mulch at the rate of 90 lbs./1000 sq. ft. Anchor mulch on steep slopes or where subjected to concentrated flow.

Determine filter strip width from Table 3 below:

Table 3. Sizing Filter Strips

Slope of Land Between Road and Stream (percent)	Minimum Width of Filter Strip For Common Logging Areas (feet)	Recommended Minimum Width of Filter Strips in Municipal Watersheds & Sensitive Areas (feet)
0-10	50 1/	100 1/
20	65	130
30	85	170
40	105	210
50	125	250
60	145	290
70	165	330
80	185	370
90	205	410

1/ A 50 foot minimum filter strip is required by law. 100 foot buffer strips are required by law along all designated scenic ponds, rivers of 25 feet or more in width and all lakes of 10 acres or more, i.e., great ponds.

V. Truck Road and Skid Road Design and Maintenance

1. Locate roads to serve the intended purpose, to facilitate the control and disposal of water, to control or reduce erosion and to make the best use of topographic features.

   On land slopes of 30 percent and greater construct cut and fill skid roads. These skid roads should have an approximate grade of 5 percent and be separated by a slope distance of at least 150 feet.

   Apply gravel or mulch with wood chips or slash to all road sections from landings to public highways.

2. Alignment. Observe the following grade limits when laying out access systems:

Landings	2-5%	
Skid Trails	3%	
	15%	Normal maximum
	20%	Maximum grade permitted for distances of 100 feet or less separated by at least 300 feet of normal grade.
Truck Roads	3%	Minimum grade
	10%	Normal grade
	12%	For maximum distances of 100 feet or less separated by 300 feet of normal grade.

3. Width. On skid roads or light duty truck roads use a minimum width of 10 feet with greater widths at curves and turnouts.

   For heavy truck traffic, the minimum tread width is 10 feet for one-way traffic and 15 feet for two-way traffic. Increase the tread width by a minimum of 4 feet for trailer traffic.

   On cut and fill skid roads and roads used for heavy trucking, the minimum shoulder width is 2 feet on each side of the tread width.

   When constructing cut and fill skid or truck roads on 30 percent or greater slopes clear a minimum 30 foot slope distance right-of-way. Leave trees at the toe of the fill slope to help stabilize the road unless they are buried with more than 1 foot of fill material. Remove (by cutting) all trees 10 feet back from the top of the cut slope to prevent them from falling into the road.

   Where turnouts are used, increase road width to a minimum of 20 feet for a distance of 30 feet.

4. Side slopes. Design all cuts and fills to have stable side slopes for the particular soil and site conditions.

   Avoid areas with geologic conditions and soils subject to mass movement or treat to prevent slides.

5. Water Control Measures

   a. Culverts for Cross Drainage of Truck Roads

      (1) For average woodland conditions, select culvert sizes from Table 4. All conditions where failure could cause extensive damage or costly delays should be referred to an engineer for design assistance.

Table 4. Sizing Pipe Culverts

Acres In Drainage Area Shallow and High Elevation Soils	Normal Forest Soils	Minimum Pipe Diameter
2	9	12*
4	16	15*
7	25	18
12	40	21
16	55	24
27	84	30
47	130	36
64	190	42
90	260	48
120	335	54
160	400	60
205	550	66
250	650	72
350	920	78

*Road repair and maintenance costs are significantly higher when culverts less than 18" diameter are used.

(2) Carefully compact earth fill around the base of all culverts to a depth equal to at least one-half the diameter of the pipe.

(3) Cover culverts with a minimum of 12" of fill.

(4) Install adequate headwalls to protect the culvert from erosion.

(5) Determine culvert spacing for cross drainage on truck roads from Table 5.

Table 5. Recommended Spacing for Ditch Relief Culverts (ft.) On Truck Roads

Road Grade Percent (%)	Spacing (feet)
1-2	500-300
3-5	250-180
6-10	167-140
11-15	136-127
16-20	125-120

b. Water Bars (See Figure 1)

Water bars are installed on truck roads, skid roads, and skid trails.

(1) Excavate water bars from undisturbed soil material and make them deep or shallow depending on the need for crossing.

(2) Minimum depth for shallow water bars is 12 inches at the outlet as measured from original ground to channel centerline.

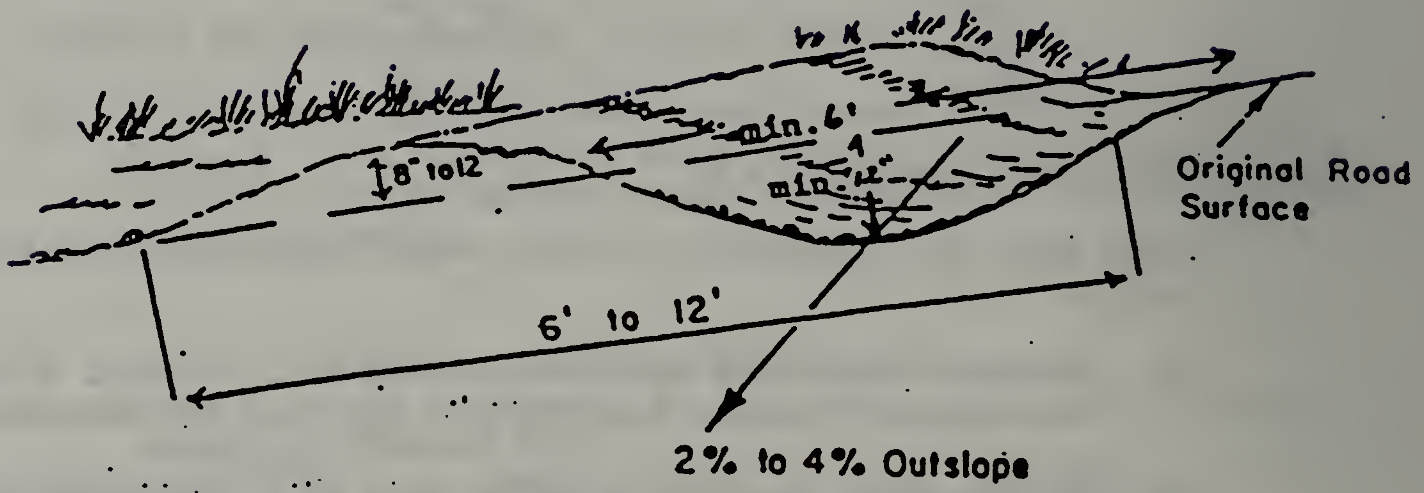
(3) Minimum top width of water bars is 6 feet as measured at the outlet section.

(4) Space water bars using Table 6 as a guide.

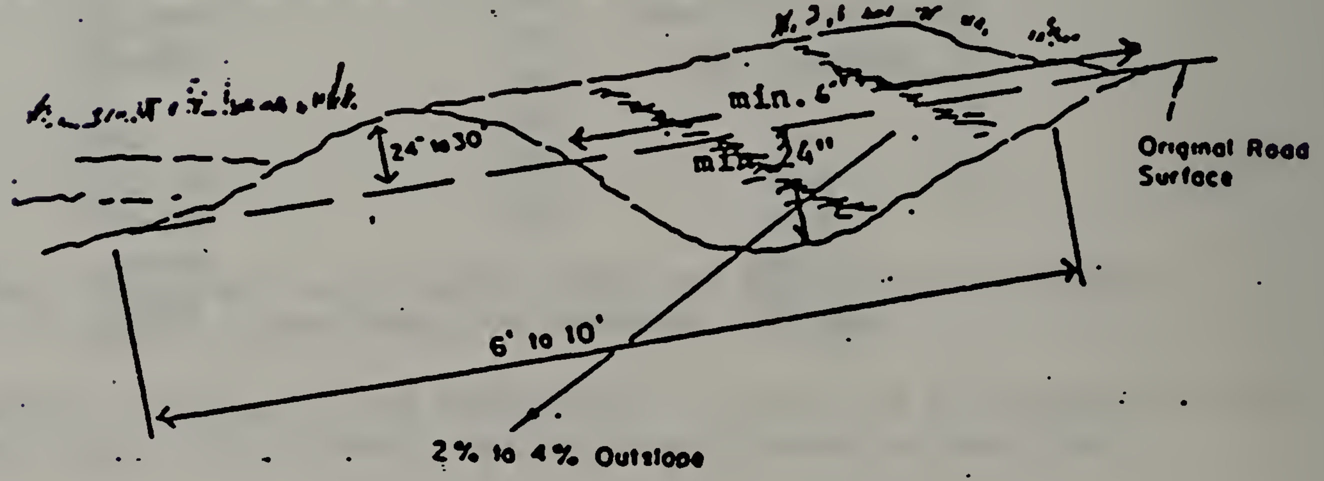
Table 6. Water Bar Spacing Guide

Road/Trail Grade Percent (%)	Spacing (feet)
1-2	250
3-5	200-135
6-10	100-80
11-15	80-60
16-20	60-45
21+	40

FIGURE 1. TYPICAL WATER BARS



SHALLOW WATER BAR



DEEP WATER BAR

c. Broad Based Dips (See Figure 2.)

(1) Install broad based dips on truck roads where no intermittent or permanent streams cross the road and the grade is 10 percent or less.

(2) On grades steeper than 8 percent, surface broad based dips with stone (approximately 3" in diameter) or gravel.

(3) Protect the outlet area with stone, grass sod, heavy litter cover, or slash.

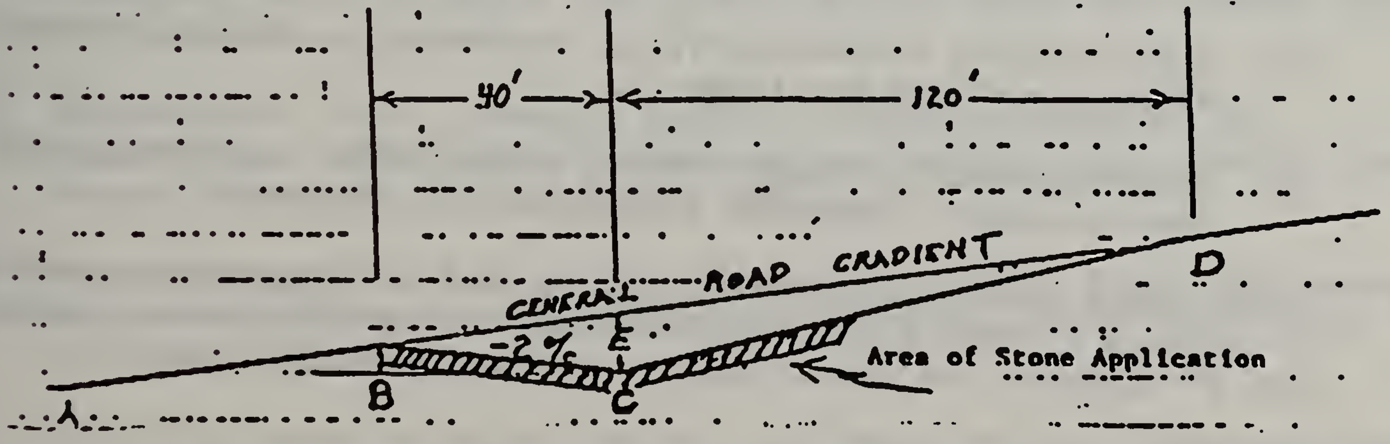
(4) Space broad based dips using Table 7 as a guide.

Table 7. Broad Based Dip Spacing Guide

Road Grade Percent	Approximate Distance Needed Between Dips (Ft.)
1	500
2	300
5	180
10	140

Figure 2. Broad Base Dip Layout 1/

2% Grade Into Dip Constant (B to C)



1/ Dips are inefficient at road gradients over 8% due to steepness of grade out of dip.

General Road Gradient	Dam Height	Depth Below Grade Maximum	Grade Out of Dip C to D
2	0.8'	1.6'	3.3
4	0.8'	2.4'	6.0
6	0.8'	3.2'	8.7
8	0.8'	4.0'	11.3

NOTE: 3% outslope at bottom of dip (4" on 12' road).
20 ton 3" stone recommended on grades over 8%.

6. Road and Water Control Structure Maintenance

   a. After storms and annually after spring thaw, the following maintenance is required:

      (1) Repair and reshape running surface, place additional gravel and/or rock as needed.

      (2) Clear obstructions and debris from ditches, culverts, and channels.

      (3) Inspect and repair water bars, broad based dips, and sediment traps.

      (4) Inspect, reset, and/or replace damaged culverts.

VI. Stream Crossing Design and Maintenance

1. Cross streams at right angles to the direction of flow and at points where the stream is narrow and banks are stable. Use culverts and bridges, as appropriate. Use water bars or broad based dips to divert surface water away from stream crossings and into a filter strip or a sediment and debris basin. Vegetate abutments and fill areas as soon as possible.

   a. Culverts for Water Crossings

      (1) Specification in Section V.5.a. "Culverts for Cross Drainage of Truck Roads" are met (Page 9).

      (2) Place culverts on firm, natural ground at or below the grade of the streambed. Negative slopes are not acceptable.

   b. Poled fords and stone crossings may be used for temporary crossing of streams if they do not create a dam. Use 8-10" diameter poles and 3" diameter and larger stone. Remove poles after use.

   c. Bridges
   Bridges vary from simple log bridges, designed to keep a skidder (and mud) out of the water or support a pick-up truck, to more elaborate structures designed to support heavy logging trucks. Bridge designs should be prepared or approved by an engineer.

   d. Maintenance of Stream Crossings
   Check all stream crossings during use, after storms, and annually to ensure that they are functional and not contributing pollutants to the stream. Temporary stream crossings should be removed when no longer needed.

VII. Sediment Control Structures

Temporary measures to control movement of soil include properly placed and maintained silt fences, hay bales and sediment traps. These will be planned specifically for each site and used at critical points to filter sediment laden water. These measures will remain in place until vegetative cover or permanent erosion control practices are established.

VIII. Supporting Data for Documentation

1. Plan map with field acreage and practice identification—soil map and topographic map.
2. Surface water controls, along with appropriate practice design and installation documentation.
3. Method of site and seedbed preparation; seed, lime and fertilizer rates.
4. Soil Loss calculations.
5. Operation and Maintenance Guidelines.

IX. References

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4. "Building Water Pollution Control Into Small Private Forest and Ranchland Roads," 1981, USDA-Forest Service and Soil Conservation Service, Pub. R6-S&PF-006-1980.
5. The Land Use Handbook Section G, Erosion Control on Logging Jobs, November 1978, Land Use Regulation Commission, Maine Department of Conservation.

6. Report of the State Forestry Committee Minimum Forest Cutting Practices Regulations, June 1987, Massachusetts Department of Environmental Management, Division of Forests and Parks.

7. Kittredge, D.B. and M.L. Parker, 1988, Massachusetts Timber Harvesting/Water Quality Handbook, Draft #3, Massachusetts Cooperative Extension Service and Massachusetts Department of Environmental Management.

8. Petersen, Christina M., 1987, The Massachusetts Forest Cutting Practices Act, Massachusetts Forest Resource Notes, Massachusetts Cooperative Extension Service, University of Massachusetts, Department of Forestry and Wildlife.

9. Massachusetts Field Office Technical Guide Technical Reference - Forestry.

X. Specification Guide

Surface water controls, design criteria, seed, lime, and fertilizer rates and Operation and Maintenance Guidelines.

ASSESSING IMPACTS OF MOTORIZED WATERCRAFT ON LAKES: ISSUES AND PERCEPTIONS

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Abstract

Discussions of impacts of motorized watercraft on lake ecology are more often emotional than scientific. Potential impacts are critically examined in light of existing data relating to motorized watercraft and water clarity, nutrient and metals concentrations, oil and gas inputs, oxygenation, shoreline erosion, rooted aquatic plant distribution, epilimnetic mixing, and interactions with invertebrates, fish, waterfowl and other aquatic wildlife. As a general rule, the negative impacts of boating outweigh benefits in terms of lake ecology alone, without consideration of social and economic factors. Negative influences are often consequences of illegal or irresponsible boating, however, and are difficult to separate from impacts caused by other human activities. Careful evaluation of lake features and user expectations is recommended before formulating lake-specific boating regulations.

Introduction

Motorized boating is many things to many people. To enthusiasts, it is freedom of motion, wind in one's hair, skipping across the water on skis, access to favorite fishing sites, and port hopping with friends. To certain other lake users, including fish and wildlife, it is a safety hazard, noisy annoyance, and source of water pollution. Most lakeside discussions are grounded in emotional response, either positive or negative. These responses are often based on long-term observations or multiple experiences which may have distinct validity, but are rarely the result of careful scientific study. As a consequence, observations from one lake system may be applied to others where the circumstances are actually quite different. A clear accounting of possible impacts and the lake features and motorized watercraft characteristics which determine the level of impact is in order.

For the purposes of this assessment, boating will be considered to include all forms of fuel-driven motorized watercraft, encompassing jetskis and boats of all sizes with outboard (two-cycle) and inboard (usually four-cycle) engines of varying horsepower. Human-powered watercraft (e.g., canoes, kayaks or rowboats), sailing vessels without auxiliary engines (e.g., smaller sailboats or windsurfers), and boats with electric motors are excluded from consideration. Additionally, no consideration will be given to less common specialty watercraft, such as float planes and snowmobiles used for the sport of watercross. Impacts of winter use of snowmobiles on ice is also not discussed. Impacts induced by recreation will be the focus of this evaluation, although commercial impacts may involve similar mechanisms.

This discussion is generally limited to ecological consequences of motorized watercraft use, although social and economic impacts often interact with ecological impacts to greatly complicate assessment and regulation. The ecological impacts of boating should be balanced with social and economic impacts in any assessment of overall impact, and it is especially important to consider non-ecological impacts when formulating regional or state-wide policies or regulations. Issues of access, crowding, safety, economic dependence, willingness to pay and lake user expectations are critical elements in any management plan.

Potential Impacts

Motorized boating activities may influence lake ecology in a great number of ways, some positive but most negative (Table 1). For the purposes of this discussion, potential ecological impacts are divided into four general categories: water quality effects, sediment quality alteration, changes in flora and influences on fauna. Impacts on water quality and sediments tend to be direct, while influences on flora and fauna may be direct or indirect.

Although most conceivable boating impacts appear adverse to lake ecology, the level of impact is highly variable, and may not be obvious or even detectable in many cases. Degree of impact is a function of both lake features and motorized watercraft characteristics. Proper evaluation of anticipated impacts is therefore dependent on an adequate understanding of key properties of the lake and the watercraft using it.

Critical Motorized Watercraft Characteristics

Properties of the watercraft and its engine can greatly affect the level of impact from the operation of the craft (Table 2). Whether the watercraft is powered by a two-cycle (usually an outboard), four-cycle (typically an inboard) or jet propulsion (e.g., jetski) engine tends to influence water quality impacts and the minimum depth of water necessary for operation. Jetskis can operate in the shallowest water, while outboards tend to operate most in at least three foot of water and inboards in depths of at least five feet. This is largely a function of engine size and associated watercraft dimensions.

Until the mid-1970's, two-cycle outboard engines were considered to be inefficient users of fuel and major contributors to water pollution by hydrocarbons, metals, phenols and oxygen-demanding substances (Jackovicz and Kuzminski 1973a). In this type of engine, oil and gasoline are mixed in a single chamber, with subsequent flow through the combustion system. Although this allows production of a relatively lightweight engine, the expense in terms of fuel efficiency and water pollution appears to have been substantial. Unburned oil and gasoline accumulated in the crankcase, and was eventually discharged to the aquatic environment (Muratori 1968, Stewart and Howard 1968, Jackovicz and Kuzminski 1973a).

It has been estimated that as much as 55% of the fuel consumed by an outboard motor was disharged unburned to the aquatic environment; the average for all outboard motors was estimated at 10 to 27% (Jackivicz and Kuzminski 1973a). Approximately 40,000 gallons of unburned fuel was being discharged annually into Lake George, New York in the late 1960's (Stewart and Howard 1968), and the estimated annual discharge of fuel into waters of the United States at that time was between 100 and 160 million gallons (Jackivicz and Kuzminski 1973a). Aside from the pollution consequences, motorboat enthusiasts were wasting millions of dollars per year in unburned fuel.

The fuel crises of the 1970's and increasing environmental awareness resulted in a number of engineering advances which greatly reduced the discharge of fuel to the aquatic environment. Recycling of fuel which accumulated in the crankcase became a standard feature in 1972 (Jackovicz and Kuzminski 1973a). Solid state ignition systems became standard in 1977, boosting the ignition voltage from 20,000 to 45,000 volts and greatly improving combustion efficiency (Jernigan 1990). Lighter, cleaner oils have been developed. Fuel waste is typically less than 1% in a well-tuned, modern engine. Unfortunately, older engines were built to last, and as many as half the engines currently in use in New England are older than 1977 (Jernigan 1990). The figure is substantially lower in the south, and nationwide the proportion of older engines on the water is probably not more than 25%.

Four-cycle engines, by comparison, have changed little over the past few decades (Jernigan 1990). Oil and fuel circulate separately, with engineering very much like automobile engines. Perceived as more environmentally sound in the 1960's and 1970's, these engines are now viewed much like those of older automobiles. Resultant pollution impacts the air more than the water, however. Jet propulsion engines are a more recent addition to watercraft, and tend to be very fuel efficient.

The size of the engine affects fuel efficiency and resultant water pollution, with larger engines (>40 hp) tending to be more efficient than smaller ones (Jackivicz and Kuzminski 1973a). Crankcase size makes a tremendous difference in a pre-1972 engine, with small crankcases wasting only an average of less than 2%; larger crankcases typically waste 30 to 50% (Jackivicz and Kuzminski 1973a). Whether the engine is tuned or untuned also affects performance, as does meeting the engine specifications for oil to gas ratio (Kuzminski and Jackivicz 1972).

The speed of engine operation is also very influential, at least for outboard engines (Jackivicz and Kuzminski 1973a). Slow speeds (idling or trolling) waste more fuel than cruising speeds, which in turn are more wasteful than racing. Unlike automobile engines, outboards apparently do not reach a peak of fuel efficiency. The difference in fuel waste between high speed and low speed operation for older engines is around 15%; the difference is likely to be much lower for modern (post-1977) engines. Additionally, the speed of engine operation determines the speed of propeller rotation, which affects the turbulence created in the water. Here the relationship between operation speed and impact is positive, however; greater speeds create more turbulence.

The speed of watercraft operation (not to be confused with the speed of engine operation, although the two are related) is another important impact-determining feature. The effect is not related to pollution from fuel, but rather to the wake created. The greater the watercraft speed, the greater the energy transfer to the surrounding environment. This does not necessarily mean that higher speeds create larger wakes, however. To understand the relationship between watercraft speed and wake, one must consider the displacement volume of the watercraft, and how it changes with speed.

Little scientific research on this topic has been encountered, but the associated mechanisms are intuitively clear. Wake is a function of water displacement, and water displacement is determined by the volume of boat below the water surface and the rate of movement. However, as the rate of movement increases, water resistance forces the hull upward and the volume of boat below the waterline generally decreases. Most small boats moving at high speeds displace less water and create less of a wake than at slower speeds, since very little of the boat is actually in the water at high speeds; air is displaced instead of water.

As the boat slows down, there is a trade-off between rate of motion and below-water boat volume, such that water displacement per unit time is roughly constant. Variation in this mid-range of speeds will depend on specific hull configuration and overall buoyancy of the watercraft. At some point during deceleration the watercraft ceases to sink into the water, and further decreases in rate of motion will result in less water displacement per unit time. The speed-wake relationship is therefore boat-specific, and is likely to have a peak at some intermediate speed. For this reason a "no wake" ordinance is likely to be more effective than establishing some moderate headway speed limit for controlling wake production. It also suggests that reduction of open water speed limits for wake reduction may have little influence, or may even increase wake production.

Liddle and Scorgie (1980) discussed the types of waves created by moving watercraft and noted the importance of both speed and boat design. In the studies cited in their review, increased speed resulted in greater wake, but the design of the boats was not revealed and the maximum speed noted was less than 10 mph. European research of this type is usually performed in canals, where speeds are limited. There are advantages to such a limited set of conditions, however, and it has been possible to model wake generation as a function of boat design, speed, cross-sectional area below the waterline, and the cross-sectional area of the canal. For a given boat design in a specified canal, an appropriate speed limit can be calculated. It was also noted that inboard engines tended to create less wake than outboard motors on similar boats at similar speeds.

The density of motorized watercraft on a lake will greatly influence impacts. A single boat is likely to do much less damage than 100 boats in the same area, although even a single boat can do great harm in a sensitive environment. How many boats are too many? There is no easy answer to that question, in light of both the variables discussed above and the salient features of lakes yet to be discussed.

Based on the viewpoints of many boaters, one boat per 25 ac of water surface is considered sufficient for all recreational boating activities (e.g., racing, skiing, fishing) (Zwick 1990). As the density of watercraft increases, or acreage per boat decreases, the resource becomes less acceptable for certain uses. Racers and waterskiers feel restricted at less than 10 ac/boat, and nearly all motorized watercraft users feel crowded at less than 5 ac/boat. This indicates something about anticipated watercraft densities for specific uses, but does not elucidate boat density-impact relationships.

In terms of water odor caused by motorized watercraft, a threshold ratio of 1.3 million gallons of water to 1 gallon of fuel consumed (English et al. 1963a) or 3.7 million to 9.3 million gallons of water to 1 gallon of exhaust discharge (Kuzminski et al. 1974) has been established for older engines. The ratio would be much higher for modern engines. At an average fuel consumption of 0.5 gal/hr (typical range for smaller recreational boats = 0.1 to 1 gal/hr), 2.6 million gallons of dilution water would be needed per hour of operation. A 100 ac lake with an epilimnetic (mixed) depth of 20 ft contains 653 million gallons of water. Without considering flushing rate or decomposition of discharged fuel, the example pond could support over 250 hours of boat operation without acquiring a detectable odor. Furthermore, it has been demonstrated that the threshold for detectable odor increases over the course of motorboat operation, as one's olfactory system becomes accustomed to the odor (English et al. 1963b).

A barely perceptible surface film one square mile in area can be created by 25 gallons of fuel, although detection of the colored sheen usually identified as an oil film requires 100 gallons of fuel per square mile (Jackivicz and Kuzminski 1973b). The film becomes very visible at 200 gal/sq.mi., and becomes a true "oil slick" at 1332 gal/sq.mi. At the 10% waste level and a fuel consumption rate of 1.0 gal/hr, a motorized watercraft operating for 8 hours would release 0.8 gallons of fuel. Over 31 such motorized watercraft would have to operate continuously for the same 8 hour period in a 640 ac area to produce a barely evident film. This represents a marginally acceptable density for boats engaged in constant motion (e.g., waterskiing, racing or sightseeing). It would therefore require a dangerous density of motorized watercraft or more than a minor spill to produce a clearly discernible oil film on a given day, even for older engines. A notable possible exception would be marina areas, where very high densities of boats fuel up and operate at inefficient motor speeds.

Frequency of traffic is partly dependent on density, but is also related to area use preferences or restrictions. In the absence of restrictions or perceived desirability of one area over another, each portion of a lake might be expected to receive as much traffic as any other. Yet boating law sets up numerous restrictions (e.g., minimum distance from a swimming area), and variability in lake features (e.g., water depth) sets up definite gradients of preference among possible boating areas. Channels and areas of least obstruction are likely to receive more motorized watercraft traffic, except where fishing is the primary use.

A careful study of the impact of traffic frequency in an English canal system (Murphy and Easton 1983) revealed threshold levels of traffic for impact on macrophyte communities through turbidity generation. During critical spring macrophyte development periods, traffic that would equate to an annual level of 300 to 600 passes per year affected macrophyte community composition. Frequencies of 2000 to 4000 passes per year generated enough turbidity to suppress most macrophyte growths.

Critical Lake Features

Many features of a lake predispose it to certain impacts and may protect it from others (Table 3). The area of a lake will determine its uses to some extent; lakes smaller than 20 ac are unlikely to experience substantial traffic by motorized watercraft, although just a few boats could influence the ecology of an entire small lake. Larger lakes are not as likely to be impacted over their entire area, but increased boating activity on larger lakes may lead to localized impacts at a variety of levels.

The volume of the epilimnion in a lake will determine the immediate volume of dilution water available to counteract pollution inputs from motorized watercraft, or to be affected by resuspension of bottom sediments. The values in Table 3 for general size categories are based on an epilimnetic depth of 20 ft and the areas listed under "Lake area", #1 in Table 3. Combining epilimnetic volume with information on the hydraulic residence time (usually on an annual basis, but preferably on a seasonal level), allows assessment of the volume of available dilution water over time and evaluation of the response of a lake to possible pollutant inputs.

The difference between the total lake area and the area of the hypolimnion is the area of the lake which could potentially be directly impacted by motorized watercraft through propeller-induced turbulence, although impacts below 10 to 15 ft of water depth seem unlikely. Assuming that thermoclines typically form at around 20 ft of water depth, the shoalness ratio also reflects the portion of the lake bottom potentially impacted by turbulence from motorized watercraft. The shallowness ratio, which compares the area of the lake under less than 5 ft of water to the total lake area, is more indicative of the lake bottom area likely to be directly affected by motorized watercraft.

Shoreline development, the ratio of the length of shoreline around the lake to the circumference of a circle with the same area as the lake, provides a size-independent measure of lake shape and indicates much about how motorized watercraft could impact the lake. Higher ratios suggest irregular shorelines with more shoreline per unit area than smaller ratios. Numerous coves may serve to isolate impacts, but there is a greater potential for shoreline impact. High ratios imply greater safety risks as well as ecological consequences.

The extent of littoral bottom coverage by rooted aquatic plants is another important lake feature when considering the impact of motorized watercraft. Extensive cover will help minimize resuspension of bottom sediments, but existing plant communities are likely to be directly and indirectly impacted by watercraft activity. The stability of plant root systems is an important feature of the plant community, as there is great variability among common macrophyte species (Liddle and Scorgie 1980). The ability of vegetative fragments to re-root and establish new plants may also magnify motorized watercraft impacts.

Finally, the nature of the bottom sediments in the pond will greatly affect motorized watercraft impacts. Fine materials will be more easily resuspended and will take longer to resettle. The presence of rocks, cobble or obstructions (e.g., stumps or boulders) will deter intensive use of shallow water where there is a danger of damage to boat hulls or propellers. The chemical composition of the sediments may mute or compound the influence of any motorized watercraft inputs with which they come in contact.

Impact Evaluation

With the above considerations in mind, the existing database for motorized watercraft impacts can be critically evaluated. This analysis will proceed through the potential influences listed in Table 1, assessing what is known of each impact and associated mitigative factors.

A. Altered water quality

1. Increased turbidity -
Motor-induced turbulence certainly has the potential to resuspend bottom sediments and increase turbidity, but how much of the turbidity observed in lakes can be attributed to motorized watercraft? Although turbidity increases from motorboating were suggested (Yousef et al. 1978) prior to 1980, there was little quantitative evidence of motorized watercraft causing appreciable turbidity (Liddle and Scorgie 1980). For example, Moss (1977) found only a very weak correlation between boating activity and turbidity, while a much stronger correlation between phytoplankton and water clarity was obtained from research on English river/canal systems. Similar results were obtained for another English river/canal system by Hilton and Phillips in 1982. Suspended solids loads from the watershed may also overshadow any affect by motorized watercraft (Horsfall et al. 1988).

More recently, however, there has been increasing evidence of motor-induced turbidity. Yousef et al. (1980) observed increased turbidity in three Florida lakes in response to recreational motorboat traffic, and demonstrated this effect with an enclosure experiment. Murphy and Easton (1983) related turbidity to boat traffic in an English canal system, and found boat-induced turbidity to be the primary mechanism controlling macrophyte community composition and biomass. A detailed study of the same English river/canal system studied previously by Moss (1977) demonstrated how a single boat could affect turbidity levels, noting an impact threshold speed of 5 mph and a recovery time of about two minutes (Garrad and Hey 1987).

A Secchi disk program involving lay monitoring of an Indiana Lake suggested increased turbidity from boating during holiday weekends (Crisman and Jones 1990). A more extensive lay monitoring program in New Hampshire used Secchi disk measurements to detect motorized watercraft impacts in multiple lakes, finding highly variable effects (Schloss 1990). Impacts were observed in water which was over 15 ft deep in some instances.

Baystate Environmental Consultants (BEC) conducted a study of motorized watercraft influence on turbidity in four Massachusetts lakes in 1988 as part of a Massachusetts Clean Lakes Program study. Periods of low and high motorized watercraft activity were monitored seven times over 48-hour periods. The results (Figures 1 and 2) strongly suggest the influence of motorized watercraft on turbidity in shallow water away from swimming areas. Unacceptable water clarity is the result of interaction between motorized watercraft and shallow water depth, fine bottom sediments, and cover by weakly rooted plant assemblages.

Oldham Pond, with the deepest average depth (12.2 ft) and lowest shallowness ratio (0.17) shows the least influence, while Furnace Pond, with the shallowest average depth (5.3 ft) and highest shallowness ratio (0.30), exhibits the most pronounced impact. Impacts were detected shortly after the onset of elevated boat activity (0.02 to 0.07 boats/ac/hr between 9 AM and 8 PM), declined over each of two nights but not to the previous day's starting level, and increased again throughout each of two weekend days (Figure 2). Conditions were considered intolerable by swimmers in all but Oldham Pond by late Saturday afternoon. Conditions during the virtual absence of motorized watercraft (Figure 1) did not change detectably, and turbidity was appreciably lower than during the period of elevated motorized watercraft useage.

Note that the density of motorized watercraft which resulted in unsatisfactory conditions ranged from 14 to 50 ac/motor, which would generally be considered an acceptable ratio for motorized activity from the perspectives of safety and user satisfaction. Note also, however, that if the state law prohibiting motorized watercraft within 150 ft of a public or private swimming area was obeyed, shallow areas would be exposed to much less motorized watercraft traffic.

2. Increased nutrient levels -
Motorized watercraft may influence nutrient levels in three ways: inputs from the motor itself, inputs from the occupant(s) of the watercraft, and resuspension/recycling of previously settled nutrients from the lake bottom or thermocline region. Phosphorus was a very minor component in leaded gasoline, but is contained at somewhat higher levels in unleaded gasoline (Jackivicz and Kuzminski 1973a). Yet the engineering advances associated with engines required to use unleaded fuel appear to have minimized release of phosphorus in exhaust. However, additives intended to improve the operation of the more wasteful older engines using unleaded gasoline contain even more phosphorus; these could be a threat to lakes with high sensitivity to phosphorus load increases.

Inputs of phosphorus from fuel may be detectable, but are apparently minor when compared with other sources. Hallock and Falter (1987) determined that phosphorus and nitrogen inputs associated with engine exhausts comprised less than one percent of the corresponding loads to a set of lakes experiencing elevated use by powerboats. A mix of engine types was involved, but the contributions from different engine groups was not quantified. BEC studies of a variety of Massachusetts lakes have accounted for nearly all of the measured phosphorus and nitrogen loads without considering motorized watercraft.

Inputs from watercraft occupants have been considered a problem in some aquatic systems (King and Mace 1974, Craig 1977, Lewis and Marsh 1977), but the problem tends to be severe only in harbor areas where large boats congregate. Furthermore, the impacts of actual watercraft users and shoreline activities are rarely separated; the impact of sewage and other waste discharges from watercraft alone in freshwater lakes is largely unquantified. Much like the problems of litter and bacterial pollution, nutrient inputs from watercraft occupants are largely a consequence of illegal or irresponsible acts; these problems are largely a function of the passengers, not the watercraft.

Resuspension and recycling of previously settled nutrients by motorized watercraft varies widely, and are highly susceptible to the modifying influences of lake features and watercraft characteristics discussed previously. In studies of multiple lakes in New Hampshire, Schloss (1990) found phosphorus load increases from motorized watercraft ranging from 8 to 80 ug/l. In lakes where internal loading is a primary phosphorus source, motorized activity can be very influential.

In field studies of Florida lakes, Yousef et al. (1980) found that the rate of increase in phosphorus content from water column agitation exceeded the rate of decrease after cessation of agitation. A net gain in phosphorus levels of 7 to 166 ug/l was observed in response to motorboat activity. In the BEC study of four Massachusetts lakes discussed above in conjunction with turbidity generation, only one (Furnace Pond) of the four lakes exhibited detectably higher phosphorus levels as a consequence of motorized watercraft activity. Furnace Pond has a highly organic, nutrient-rich muck with a low specific gravity, while the other three ponds have greater portions of sand in their bottom sediments.

3. Increased hydrocarbon concentrations -
Hydrocarbon emissions from motorized watercraft are similar to those produced by automobiles, with over 100 possible compounds released at detectable levels (Jackivicz and Kuzminski 1973a). Many of these will not persist in water, however, due to volatility and natural degradation processes. Additionally, actual inputs are not readily visible during most operational speeds, as propeller-induced turbulence rapidly mixes exhaust discharge with surrounding lake water. Phenolic compounds have been cited as the most troublesome exhaust component (English et al. 1963a), and Kuzminski et al. (1973) indicated that the bulk

of the emitted hydrocarbons were components of unburned fuel. This problem has been greatly diminished by engineering advances of the last two decades.

Given the volume of fuel necessary to produce a visible oil film, visual detection of motorized watercraft impacts outside of marinas is unlikely. Even within a marina, runoff from adjacent parking lots may prove to be a greater source of hydrocarbon films than watercraft. Chemical detection is possible, but the capacity of natural systems to attenuate impacts is often surprising. Key questions regarding impacts on flora and fauna will be addressed later in this discussion.

4. Increased metals levels -
Although there has been considerable research on the concentrations of metals in aquatic sediments and biota, and those metals must travel through the water to reach the sediment or organisms, there is little documentation of elevated metals levels in water as a consequence of motorized watercraft activity. Metals are fairly rapidly sequestered in the sediments (Kuzminski and Mulcahy 1974), and are recycled through biological processes and some chemical reactions at low pH. If one cannot find elevated levels of a particular metal in the sediments, the overlying water is unlikely to contain a detectable level of that metal.

5. Increased oxygenation -
Turbulence created by motorized watercraft would apear to have the potential to increase mixing at least near the surface of a lake, and would thereby be expected to increase oxygen transfer from the atmosphere to the lake. Yousef et al. (1980) observed a very limited and statistically insignificant increase in dissolved oxygen levels in their Florida study lakes, despite appreciable changes in turbidity and phosphorus concentration. Dissolved oxygen levels were near saturation throughout experiments, however, limiting the potential for oxygen increases.

Hallock and Falter (1987) observed no increase in dissolved oxygen levels in enclosures subjected to eight hours of outboard engine use, and noted that discharge of oxygen-demanding substances resulted in a detectable decrease in oxygen levels for as much as 12 days after motorized test runs. Similarly, the literature reviewed by Milliken and Lee (1990) suggested oxygen reductions in marina areas related to sewage discharges; oxygenation by propeller-induced turbulence was apparently insufficient to counteract oxygen demand.

Motorized watercraft do not appear to be a significant force in aeration of lakes. Aside from the counteraction of discharged oxygen-demanding compounds, the real potential for oxygen levels to be increased by motorized watercraft should be carefully considered. The rate of transfer of oxygen to an aquatic environment can be described by the O'Connor-Dobbins equation (Weber 1972):

$$k = (D_l * v/h^3)^{0.5}$$

where k = transfer coefficient
D_l = diffusion coefficient = 0.001944 ft^2/day @ 20°C
v = velocity in ft/day
h = depth of mixing, arbitrarily set at 10 ft here

The difference between a lake surface impacted only by normal winds and a lake surface disturbed by motorized watercraft will be reflected in the velocity term, v. Assuming a watercraft speed of 25 mph (37 ft/sec or 3.2 million ft/day) and a normal, quiescent mixing speed of 0.01 ft/sec (864 ft/day), the resulting values for the transfer coefficient, k, are 2.48/day for the motor-impacted area and 0.04/day for the undisturbed lake. While this suggests that motorized watercraft can greatly elevate the transfer coefficient, the affected area must also be considered in predicting the overall contribution.

Given a single motorboat operating at 25 mph and causing complete mixing in an area 10 ft wide, 367 sq.ft of lake area will be affected by the altered transfer coefficient every second. In a 100 ac lake during that same second the natural transfer coefficient will be in affect over an area of 4,356,000 sq.ft. Weighting the transfer coefficients by the respective areas affected per unit time, the motorboat raises the rate of oxygen transfer by only 0.5%. In a 100 ac lake, the number of high-speed watercraft operating simultaneously should certainly not exceed 10, suggesting a maximum increase in aeration potential of 5% under the specified conditions. It is therefore highly unlikely that motorized watercraft will have any detectable positive impact on the dissolved oxygen level of a lake.

6. Increased contamination by pathogens -
The release of pathogens from motorized watercraft activity is a function of sewage discharges, and falls into the same category as nutrient inputs by watercraft occupants. It is a people management problem, not just a motorized watercraft issue. Release of pathogens is generally monitored through assessment of fecal bacterial levels, although total coliform standards are used as well.

Little impact was detected by some researchers who lumped in-lake and shoreline activities (Rosebery 1964, Carswell et al. 1969, Canter 1976). However, differences in bacterial levels between reservoirs where recreation was allowed and those where it was not are evident (Minkus 1965, Carswell et al. 1969); they are simply not great enough to warrant extreme precaution where treatment of water supplies is routine. The use of bacteria as surrogates for pathogenic contamination and various aspects of study design have been criticized (Carswell et al. 1969), however, suggesting the need for more detailed investigations.

Gibson et al. (1986) have pointed out the potentially overshadowing impact of wildlife populations and urban pets on water resource microbiology, but note that most violations of health standards appear to be related to high intensity recreational use. Marinas are particularly susceptible to problems of this nature, presumably through inadequate or disregarded waste disposal provisions. Milliken and Lee (1990) noted that several studies had established a positive correlation between fecal coliform bacteria concentrations and boat densities, but that no direct link between boating and the incidence of disease had been demonstrated. Other studies reviewed by Milliken and Lee indicated no correlation between fecal bacteria and boats, however, and suggested an overriding influence by land-based sources of bacteria.

In cases where boat inputs were believed to be the primary source of fecal bacteria, a ratio of 26 to 58 million gallons of water to each boat has been suggested to maintain a fecal coliform concentration less than 14/100 ml (Milliken and Lee 1990). This is the standard for marine shellfish harvest; adjustment to the freshwater contact recreation standard of 200/100 ml yields a ratio of 2 to 4 million gallons (700 to 1540 cubic meters) of water to each boat. This ratio may be hard to meet in marina situations, but represents no problem in most open water areas.

7. Changes in taste and odor -
The sensory properties of water can certainly be affected by exhaust discharges from motors (English et al. 1963a, 1963b, Kuzminski et al. 1974), but the quantities necessary to impart a perceptible taste or odor would necessitate a high density of motorized watercraft. While the need for millions of gallons of dilution water per gallon of exhaust discharge may seem high, the water volumes typically encountered in the open lake environment are far greater. Persistent problems are therefore likely to arise only in confined areas with high motor density, such as marinas.

B. Altered sediment quality

1.a. Redistribution of particles: shoreline erosion -
Waves generated by motorized watercraft may create a shoreline erosion hazard if the shoreline condition is susceptible to erosion. Key factors in determining erosion susceptibility are soil condition and vegetative cover, each of which can be altered by shoreline activity (Settergren 1977, Horsfall et al. 1988).

Shoreline use patterns and resultant conditions are therefore of paramount importance to determining the impact of motorized watercraft on shoreline erosion.

Impact variability is expected to be much like that of turbidity generation or alteration of nutrient levels. Cases of severe erosion have been documented (Liddle and Scorgie 1980), but conclusive separation of motorized watercraft impacts from wind-generated wave activity and land-based runoff damage are rare. Shoreline erosion at watercraft input points has been documented (Densmore and Dahlstand 1965, Hansen 1975), but this is not a function of motor activity.

1.b. Redistribution of particles: littoral zone changes -
Given the distinct potential for motorized watercraft to resuspend previously settled particles (Yousef et al. 1980, Garrad and Hey 1977), redistribution of particles within a lake seems quite plausible. Studies of such phenomena are lacking, however, and observational data suggest no obvious effects. It seems likely that particles would be vertically stratified with the finest material on top, and that there would be an eventual loss of fine material from shallow areas as it is resuspended and carried to deeper portions of the lake. Lagler et al. (1950) observed alteration of benthic invertebrate communities and suggested that some habitat modification was occurring through redistribution of fine sediments, but other mechanisms were not ruled out.

2. Increased nutrient accumulations -
Given the lack of evidence for marked increases in actual nutrient inputs by motorized watercraft, it appears that there is no reason to assume any appreciable accumulation of nutrients in the sediments as a consequence of motorized watercraft activity. If such accumulations are to be found, they would be in marina areas. If elevated sediment nutrient levels are not found in areas of extensive boat mooring, there is little likelihood of finding watercraft-related increases in nutrients in offshore sediments.

3. Increased hydrocarbon accumulations -
Although spills can create extensive and lasting hydrocarbon accumulations in aquatic sediments, the potential for inputs of the necessary magnitude to freshwater lakes is limited to marinas. Contamination in marinas has been found to be severe in some cases (Broman 1984) and minimal in others (Nixon et al. 1973), based on documented biotic impacts. Given the lighter nature of fuels, accumulations are rather different than those associated with crude oil spills; much of the fuel hydrocarbon

content is volatilized or forms an emulsion with water and never reaches the lake bottom (Jackivicz and Kuzminski 1973a). The potential for meaningful contamination exists, but each potential case should be assessed on its own merits.

4. Increased metals accumulations -
Metals enter the aquatic environment from motor exhausts (Jackovicz and Kuzminski 1973a, Pecor and Novy 1973) and from leaching from anti-fouling paints (Alliot and Frenet-Piron 1988, Balogh 1988). Since anti-fouling paints are generally used for marine situations, they should not be a major factor in metals accumulations in smaller freshwater lakes. Metals in engine exhausts have been more of a factor in the past than they are today (Jernigan 1990), but the sediments contain evidence of past abuses which can affect lake ecology in the present.

Lead is the metal most commonly associated with engine exhaust, but cadmium, tin and other metals can also be released in detectable concentrations and accumulate in lake sediment (Byrd and Perona 1979, Makker et al. 1989). Studies of sediment composition are unlikely to definitively isolate motorized watercraft as the source for these metals, as land-based sources complicate data interpretation (Koppen and Souza 1984), but a very likely relation of metals accumulations to motorized watercraft density has been established in several cases (Byrd and Perona 1979, Makker et al. 1989). The potential impacts of these accumulations are addressed in the sections of this discussion devoted to flora and fauna.

C. Altered flora
1. Epilimnetic mixing of phytoplankton -
The turbulence introduced by motorized watercraft certainly has the potential to mix the phytoplankton community in the upper water layer of a lake (Yousef et al. 1978, 1980), and could be a factor in minimizing surface scum formation in small lakes. As with the impact of motorized watercraft on oxygen levels, however, the effect of motor-induced turbulence is likely to be minor when compared to natural processes such as wind-induced mixing or massive rises of vacuolate cyanophytes. Heavily travelled boating lanes may experience some surface scum control, however, at least during normal boating hours.

In much the same way as watercraft have the potential to disrupt surface accumulations of algae, they have the potential to stir up bottom-dwelling mats of filamentous algae in shallow areas (Schloss 1990). These mats sometimes rise to the surface as a consequence of trapped gas bubbles, but this process may be short circuited by turbulence from motorized watercraft. In addition to stirring up the algal mats themselves, motorized watercraft may facilitate resuspension of associated nutrient-rich sediment particles that may then fuel additional algal growth.

2. Inhibition of algal growth -
Although concentrated solutions of motor exhaust have been shown to be detrimental to phytoplankton growth (Stewart and Howard 1968, Kuzminski and Fredette 1974), water from lakes or coastal areas which have been impacted by motorized watercraft had little negative effect on phytoplankton growth (Nixon et al. 1973, Fredette and Kuzminski 1974). Walsh et al. (1985) suggested that organotins derived from boating activity could be a hazard to diatoms in areas of heavy motorboat traffic, based on toxicity at fairly low concentrations. In standard bioassays it took a dilution ratio of less than 13,333 gallons of water to one gallon of engine exhaust to inhibit the growth of Selenastrum, and a ratio of less than 3333:1 to kill the algae (Kuzminski and Fredette 1974); natural dilution ratios tend to be much higher, even in marinas.

Yet data which indicate toxicity of engine-derived hydrocarbons to plankton at much lower concentrations exist, and it has been suggested that toxicity assays should employ natural assemblages of organisms (Horne 1990). Even if the productivity of the natural assemblage is not detectably altered, there may be substantial shifts in species composition or relative abundance. There appear to be many influential variables here, yielding a wide range of possible responses. Nevertheless, normal levels of outboard motor usage have not been shown to have distinctly toxic effects on aquatic communities (Milliken and Lee 1990).

3. Stimulation of algal growth -
There is little evidence of any stimulatory effect of motor exhaust on growth. Kuzminski and Fredette (1974) found no increase in growth rates of Selenastrum in standard bioassays employing engine exhaust, and Nixon et al. (1973) found no increase in planktonic production in a marina area over a nearby marsh habitat. This is generally consistent with the lack of evidence for substantial nutrient inputs from motorized watercraft, but these studies did not address lakes with very low nutrient loading.

Although inputs from motorized watercraft do not appear to have a consistently substantial impact on algae, increased nutrient levels caused by motor-induced turbulence can stimulate algal growth (Yousef et al. 1980). The increase in nutrient levels may be offset to some extent by reductions in light intensity and spectral quality changes, but the net effect of motorized watercraft traffic appears to be an increased potential for phytoplankton growth. This potential may be overshadowed by land-based inputs, however (Horsfall et al. 1988), and should be assessed on a case by case basis.

4.a. Inhibition of rooted plant growth: direct damage - The direct impact of motorized watercraft on rooted plant communities is a function of the depth of those communities below the water surface, the rooting stability of the species in the community, and the force exerted by the watercraft. Lagler et al. (1950) noted that a motorboat could effectively remove all rooted vegetation at a water depth of less than 3 ft. Liddle and Scorgie (1980) separate plants into four categories of rooting stability, based on ease of removal, and discuss the forces generated by motorized watercraft.

Aside from direct contact with the propeller, which can remove the growing tip of submerged plants, abrasion from boat hulls can damage or destroy aquatic macrophytes (Liddle and Scorgie 1980). Recovery from disruption of the root system of some plants can be very slow, leaving bare patches of erodible sediment or allowing replacement by other species (Zieman 1976). BEC divers have observed areas where swaths of *Najas flexilis* and *Nitella flexilis*, two rather weakly rooted species, have been removed by propeller action during the initiation of waterskiing runs in water up to 10 feet deep.

Although the above mechanisms of direct disturbance are known, the actual extent of direct physical damage to rooted plants by motorized watercraft in specific aquatic systems is largely unknown. Most direct impacts are likely to take place in shallow water (<5 ft), while indirect impacts dominate in deeper lake areas.

4.b. Inhibition of rooted plant growth: indirect suppression - The primary means for indirect suppression of rooted aquatic plants by motorized watercraft is generation of turbidity, with the level and timing of turbidity generation having prime importance (Murphy and Easton 1983). In 50% of the canals studied, the threshold of 2000 to 4000 motorboat passes per year necessary to generate enough turbidity to eliminate rooted macrophytes was attained; 24% exceeded the 2000 passes/yr level and 26% surpassed the 4000 passes/yr frequency. It was also found, however, that plant assemblages were altered if a frequency equating to 300 to 600 passes per year was maintained during the critical spring development period.

As many factors contribute to generation of turbidity by motorized watercraft, it is necessary to carefully assess lake conditions and characteristics of the watercraft on the lake before estimating likely impacts on the rooted plant community. Additionally, the other uses of the lake must be considered. Except in heavily trafficked boating lanes, it is unlikely that the necessary level of turbidity will be sustained or accepted by other lake users (e.g., swimmers). Management actions would probably be demanded before conditions degraded to the point where widespread rooted plant die-off occurred. More subtle effects relating to spring peaks of turbidity generation (e.g., around the Memorial Day holiday weekend) are more likely to occur, but have not been documented in lakes.

5. Dispersal of rooted plants -
Motorized watercraft may aid dispersal of plants within lakes and between lakes. It is difficult to separate the impacts of watercraft from those of waterfowl and water currents, however, and few conclusive studies have been completed. As vegetative fragments cut from rooted plants by propellers have been observed to take root and start new plants (pers. obs.), the potential for intra-lake spread of nuisance species by motorized watercraft is clear.

The rapid spread of certain nuisance species (e.g., Myriophyllum spicatum) among the lakes in a region has been attributed to trailered motorboats by government agencies, but careful studies are not plentiful. Newroth (1979) demonstrated inter-lake dispersal by motorized watercraft in British Columbia, Canada, and a very insightful study was performed by Johnstone et al. (1985) in New Zealand. This latter study found that the distribution of nuisance species in 107 lakes strongly indicated watercraft as prime vectors. Of the motorized watercraft on 14 surveyed lakes, 27% had come from another lake. Only 5.4% of motorized watercraft leaving these lakes carried viable plant fragments, however. The probability of a boat leaving the water with viable plant fragments increased with increasing plant density in the vicinity of the boat ramp. Successful transfer among lakes declined with increasing distance between lakes, up to a maximum distance of about 76 miles.

D. Altered fauna

1. Collision-induced mortality -
Most fish and wildlife can successfully avoid collisions with watercraft, so collision-induced mortality is a somewhat unusual occurrence. An exception is presented by the manatee in Florida, which has been subjected to substantial mortality as a consequence of motorized watercraft traffic. O'Shea et al. (1985) found that out of 219 manatee deaths that could be attributed to known causes, 87 were the result of collisions with motorboats and and at least 55 others were related to other human activities. Richardson et al. (1985) found that whales responded to boat noises (actual or recorded) with evasive actions, and similar responses have been assumed for fish.

2. Reduced reproductive success -
In a classic 1950 study, Lagler et al. examined the effects of motorboats on warmwater fish populations and found no significant impacts that could be clearly linked to the boats. There was no significant mortality of spawning adults or fry, and production

between the motor pond and the control pond was similar. Adults fled from nesting sites as boats approached, but returned as soon as the boats passed. The only mechanism of fish mortality considered likely was destruction of eggs and nests by motor-induced turbulence in very shallow (<2 ft) water. No overall impact on bass and sunfish populations from this mechanism was detected, however.

Many researchers (e.g., Galhoff et al. 1984, Koepth and Dietrich 1986) have documented evasive flights of waterfowl in response to motorized watercraft approaches, but the impact on the reproductive success of such waterfowl has only recently received focused attention. Ahlund and Gotmark (1989) found that predation on eider ducklings by gulls increased by 200 to 300% in the presence of motorized watercraft. Predation took place primarily when the adult eider ducks were scared away from their nests by watercraft. The proximity of gulls to the nesting area and the frequency of boat traffic were found to be the most important variables in determining predation rates.

Watercraft can increase human disturbance of nests simply by making nesting areas more accessible, but such impact is not restricted to motorized watercraft and is a function of irresponsible human actions, not the watercraft itself. Ream (1979) discusses the stresses placed on wildlife by intentional and unintentional human actions associated with recreation of all types, and notes that increased education of recreationists could go a long way toward minimizing impacts.

There has been speculation that loon populations in North America have been negatively impacted by motorized watercraft, but the largest threat to these birds is methylated mercury compounds which do not appear to be a result of motor useage (McIntyre 1989). Certainly these birds and other species are sensitive to human presence, however, and intensive motorized watercraft traffic may reduce waterfowl use of affected lakes (Horsfall et al. 1988).

3. Changes via food resource modification -
Motorized watercraft can alter the food resource base in a lake by stirring up the bottom sediments in shallow areas. Lagler et al. (1950) postulated that reductions in invertebrate densities in very shallow water in their motor pond were related to predation by sunfish and bass when the invertebrates were washed from safe hiding by motorboats. Trout have been observed to gorge themselves on large dragonfly nymphs, Anax, and smaller damselfly nymphs, Enallagma, when the bottom of the shallow pond was severely agitated (pers. obs.). Even extreme turbidity did not prevent greatly elevated predation on the exposed nymphs. Bluefish in bays have also been observed to congregate behind boats stirring up the mud in shallow waters (pers. obs.), and

dolphins have been known to cluster in the vicinity of shrimp boats (Leatherwood and Reeves 1983). How much influence such activity has on fish growth or invertebrate densities in freshwater environments is generally unknown.

The activities of fisherman can affect food resources, either by what they take out of the system or what they put in. Intense fishing tends to alter the size structure of fish communities and can have a cascading effect on other portions of the food web (Kitchell and Carpenter 1987), although such fishing is not strictly dependent on motorized watercraft. Shorebird assemblages can be structured by the wastes available from fishing fleets (Hudson and Furness 1989), although the magnitude of such influences in smaller recreational lakes is likely to be negligible.

4.a. Changes via habitat modification: physical habitat - Although Lagler et al. (1950) suggested that motorboats in water less than 3 ft deep could impact fish and benthic invertebrate habitat, quantitative studies of physical habitat alteration are rare. The forces exerted by motorized watercraft traffic are generally within the range of naturally occurring actions (e.g., waves, mixing), and would not be expected to detectably change the physical habitat over large areas except under very unusual circumstances.

If the littoral or shoreline habitat was altered, however, this would have a very probable impact on its faunal residents. Impacts of motorized watercraft on reptiles and amphibians have been virtually undocumented, but indirect impacts through habitat modification are certainly possible. Careful consideration of the features of a lake which might make it prone to such changes in habitat is warranted, but there is no clear research basis for assuming any impact.

4.b. Changes via habitat modification: chemical habitat - Substances discharged from motors during operation can be toxic to fish and aquatic invertebrates, but not at typically occurring concentrations. Lagler et al. (1950) found no chemical effects on fish or invertebrates in a pond subjected to substantial use by motorized watercraft. Nixon et al. (1973) found little difference between the faunal assemblage in a marina and that in a nearby marsh which was largely unaffected by boat traffic. Neither water quality nor sediment condition were found to detectably influence biotic structure in these cases.

Bioaccumulation of metals or other substances could have long-term effects on benthic dwellers, suspension feeders and their predators, but non-lethal effects are difficult to measure and separate from other influences. Horsfall et al. (1978) found only low levels of lead in sponges from a heavily boated lake, and concluded that there was no discernible influence on the sponge population of the lake by motorboats. Yet Balogh (1988) found higher levels of zinc, copper, cadmium and lead in mussels in a boat harbor in Lake Balaton, Hungary, than in nearby open waters, and suggested a detrimental effect on the harbor population from antifouling agents on boat hulls

In bioassay tests (Kuzminski et al. 1974) scud were found to be adversely affected by a solution of 3% motor exhaust water, while dragonfly nymphs were not negatively impacted until the exhaust concentration was increased to at least 15%. Bluegill sunfish and fathead minnows were not typically affected by less than a 20% solution of exhaust (Kuzminski and Jackivicz 1972). Typical dilution of engine exhausts in even a marina setting would result in exhaust concentrations of far less than 1%, suggesting that observable mortality from chemical contamination of lakes by motorized watercraft is unlikely.

Chronic toxicity occurred at lower concentrations, but the toxicity of exhaust solutions declined markedly over a period of about two weeks (English et al. 1963a). Unless motorized watercraft use is persistently elevated in an isolated area with limited flushing, chronic effects are highly improbable.

5. Flesh tainting -

Although organisms may not be killed by the substances released by motorized watercraft, more subtle effects are possible. Behavioral changes have not been well studied, but tainting of fish flesh has received some attention by virtue of its bearing on recreational fishing interests. English et al. (1963a, 1963b) found that discernible tastes occurred in several warmwater fish species after multiple weeks of exposure at dilution ratios less than 6,000,000:1. The maximum dilution that produced flesh tainting is of the same magnitude as the odor threshold. Therefore, if there is no water odor, fish flesh tainting is unlikely.

Managing Motorized Watercraft Impacts

From the above discussion, it should be clear that there are few if any "rules of thumb" by which motorized watercraft management should be governed. It is essential that the features of the lake and the watercraft using it be considered in any evaluation of probable impacts. Probable impacts will vary widely among systems. If one wishes to successfully manage motorized watercraft on a lake, it is critical that the goals of such management be derived in a logical fashion and be clearly stated.

In setting goals, it is highly desirable to assess the lake user community, including human and non-human elements, and to quantify human user preferences and expectations for the resource. Determining the management objectives will involve evaluating and balancing ecological, social and economic considerations, and often falls into the realm of politics. Once the goals of management are set in place (which is much easier said than done), the appropriate strategies for achieving those goals can be intelligently screened.

Motorized watercraft restrictions fall into just a few categories. Prohibition of all or certain types of motorized watercraft is the most severe restriction, but is often warranted. A regional perspective on boating opportunities is helpful when considering prohibition of motorized watercraft for a given lake. The use of prohibition is justified when safety considerations are paramount or when the minimum anticipated level of impact on the lake ecosystem is inconsistent with management objectives.

A more subtle and less discrimminatory form of prohibition involves restricting access. If there are only a few spaces in the parking area associated with a boat launch, the number of watercraft brought to the lake for use will be limited. A limited number of passes can be made available for watercraft use on a controlled lake, after which access is denied. Such access restrictions may limit density, but will not necessarily eliminate impacts by motorized watercraft and may be perceived as unfair by lake users.

Horsepower limits represent a modified form of prohibition, which addresses engine size but not watercraft design or operational features. Speed limits address the operational features in a general way, but do not consider engine size or watercraft design. Horsepower limits are easier to implement and enforce than speed limits, while speed limits are more likely to minimize disruptive ecological effects than horsepower limits. Either may be construed as unfair or arbitrary by some user groups for logical reasons. If either horsepower or speed limits are to be employed, it is advisable to base the established limit on a scientifically defensible rationale and the specific characteristics of the lake in question. Blanket coverage of a region by these limits is apt to be inappropriate.

The most flexible approach to motorized watercraft restrictions involves time and/or space zoning of the lake. Time zoning of a lake involves setting hours for motorized transport and other uses as well, or establishing a schedule of rotating days for specific uses. In Eastham, MA, for example, motorized watercraft are permitted on odd numbered days, allowing windsurfers, sailboats, canoes and other non-motorized watercraft to have the run of this 110 ac lake on even numbered days. Conditions are such that any turbidity generated on odd numbered days has subsided to minimal levels by the morning of even numbered days.

Such regulations were considered necessary to accommodate elevated pressure from competing uses in this summer resort community.

Other uses of time zoning include "quiet hours" during which more passive recreational pursuits can be enjoyed, waterskiing hours in which the majority of lake surface is devoted to skiing, and fishing periods during which fishermen can practice their art free of distraction. The key is in reaching a consensus among user groups that satisfies the greatest number of users for the greatest amount of time while preserving desirable lake qualities.

Space zoning involves setting aside portions of a lake for specific uses (Engel 1989). Aside from establishment of supervised swimming areas, space zoning is likely to be acceptable only in larger lakes where sufficient space is available for each use. Space zoning allows key habitat areas to be set aside, can restrict motorized watercraft to areas of least potential impact, protects the best fishing spots from disturbance, and promotes safe swimming. When space zoning is applied, appropriate lake management techniques for each area of the lake can be selected. The reduced scale of implementation for each technique (e.g., harvesting, aeration) may lead to a cost savings and allows area-specific fine tuning of each technique for maximum effectiveness.

Conclusions

The many possible impacts of motorized watercraft are determined by a complex combination of lake and watercraft characteristics which is unique to each lake or at least each lake type. It is therefore critical to have a clear understanding of the relative importance of each factor and its role in the system under scrutiny. As regulatory approaches to managing motorized watercraft are limited in diversity and are restrictive by intent, it is essential to make wise choices based on sound scientific information and relevant social and economic issues.

The impacts of motorized watercraft appear to be largely density dependent; increased use translates into increased potential for impact. Some impacts have relatively distinct thresholds, however, so the relationship between density and impact is not always linear. Many impacts are most likely to occur in marina situations, suggesting that if effects are not observed in marinas they will probably not be detectable in the lake. Similar impacts from other sources may overshadow those from motorized watercraft, and it is not always possible to separate the effects of motorized watercraft from those of other watercraft or land-based activities. Alternative explanations for observed impacts must be considered in management decisions.

The potential negative impacts of motorized watercraft appear to greatly outnumber possible positive effects. It is therefore not reasonable to claim that the aquatic environment benefits from motorized watercraft use. As the types and levels of impact can vary so tremendously between lakes, however, it is also not reasonable to assume that motorized watercraft will have a detectably detrimental impact on a given water resource. Restrictions and performance standards should be set on a case by case basis, with regional coordination to maximize satisfaction of demand for specific uses within an appropriate geographic range.

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TABLE 1.
POTENTIAL MOTORIZED WATERCRAFT IMPACTS ON WATER RESOURCES AND ASSOCIATED BIOTA

A. Altered water quality
  1. Increased turbidity
  2. Increased nutrient levels
  3. Increased hydrocarbon concentrations
  4. Increased metals levels
  5. Increased oxygenation
  6. Increased contamination by pathogens
  7. Changes in taste and odor

B. Altered sediment quality
  1. Redistribution of particles
     a. Shoreline erosion
     b. Littoral zone changes
  2. Increased nutrient accumulations
  3. Increased hydrocarbon accumulations
  4. Increased metals accumulations

C. Altered flora
  1. Epilimnetic mixing of plankton
  2. Inhibition of algal growth
  3. Stimulation of algal growth
  4. Inhibition of rooted plant growth
     a. Direct damage
     b. Indirect suppression
  5. Dispersal of rooted plants

D. Altered fauna
  1. Collision-induced mortality
  2. Reduced reproductive success
  3. Changes via food resource modification
  4. Changes via habitat modification
     a. Physical habitat
     b. Chemical habitat
  5. Flesh tainting

TABLE 2.
CHARACTERISTICS OF MOTORIZED WATERCRAFT WHICH INFLUENCE ECOLOGICAL IMPACT ON LAKE ECOSYSTEMS

1. **Type of engine**
   a. Two-cycle
   b. Four-cycle
   c. Jet propulsion

2. **Engine design/age**
   a. Conventional
      (most pre-1977 engines)
   b. Modified for fuel efficiency

3. **Size of engine**
   a. Small (<20 hp)
   b. Medium (20-100 hp)
   c. Large (>100 hp)

4. **Crankcase size**
   (relative to engine size)
   a. Small
   b. Large

5. **Engine condition**
   a. Tuned
   b. Untuned

6. **Fuel ratio (gas:oil) and oil type**
   a. Meets engine specifications
   b. Differs from specifications

7. **Speed of engine operation**
   a. Idle or trolling (<1500 rpm)
   b. Cruising (1500-2500 rpm)
   c. Racing (>2500 rpm)

8. **Speed of watercraft operation**
   a. Slow (<5 mph)
   b. Medium (5-15 mph)
   c. Fast (15-30 mph)
   d. Very fast (>30 mph)

9. **Displacement of water**
   a. Low (<5 cubic yards)
   b. Medium (5-15 cubic yards)
   c. Large (15-30 cubic yards)
   d. Very large (>30 cubic yards)

10. **Density of motorized watercraft**
    a. Low (>25 ac/boat)
    b. Medium (10-25 ac/boat)
    c. High (5-10 ac/boat)
    d. Very high (<5 ac/boat)

11. **Frequency of traffic**
    a. Rare (<100 passes/yr)
    b. Low (100-1000 passes/yr)
    c. Medium (1000-2000 passes/yr)
    d. High (2000-4000 passes/yr)
    e. Very high (>4000 passes/yr)
    (Also consider daily/weekly/
    seasonal pattern of use)

TABLE 3.
CHARACTERISTICS OF LAKE ECOSYSTEMS WHICH INFLUENCE ECOLOGICAL IMPACT BY MOTORIZED WATERCRAFT

. **Lake area**
   a. Low (<20 ac)
   b. Medium (20-100 ac)
   c. Large (100-300 ac)
   d. Very large (>300 ac)

2. **Epilimnetic volume**
   a. Low (<130 million gal)
   b. Medium (130-653 million gal)
   c. Large (653-1960 million gal)
   d. Very large (>1960 million gal)

3. **Hydraulic residence time**
   a. Low (<21 days)
   b. Medium (21-90 days)
   c. High (90-365 days)
   d. Very high (>365 days)

. **Shoalness ratio**
   (area <20 ft deep/total area)
   a. Low (<0.25)
   b. Medium (0.25-0.50)
   c. High (0.50-0.75)
   d. Very high (0.75-1.00)

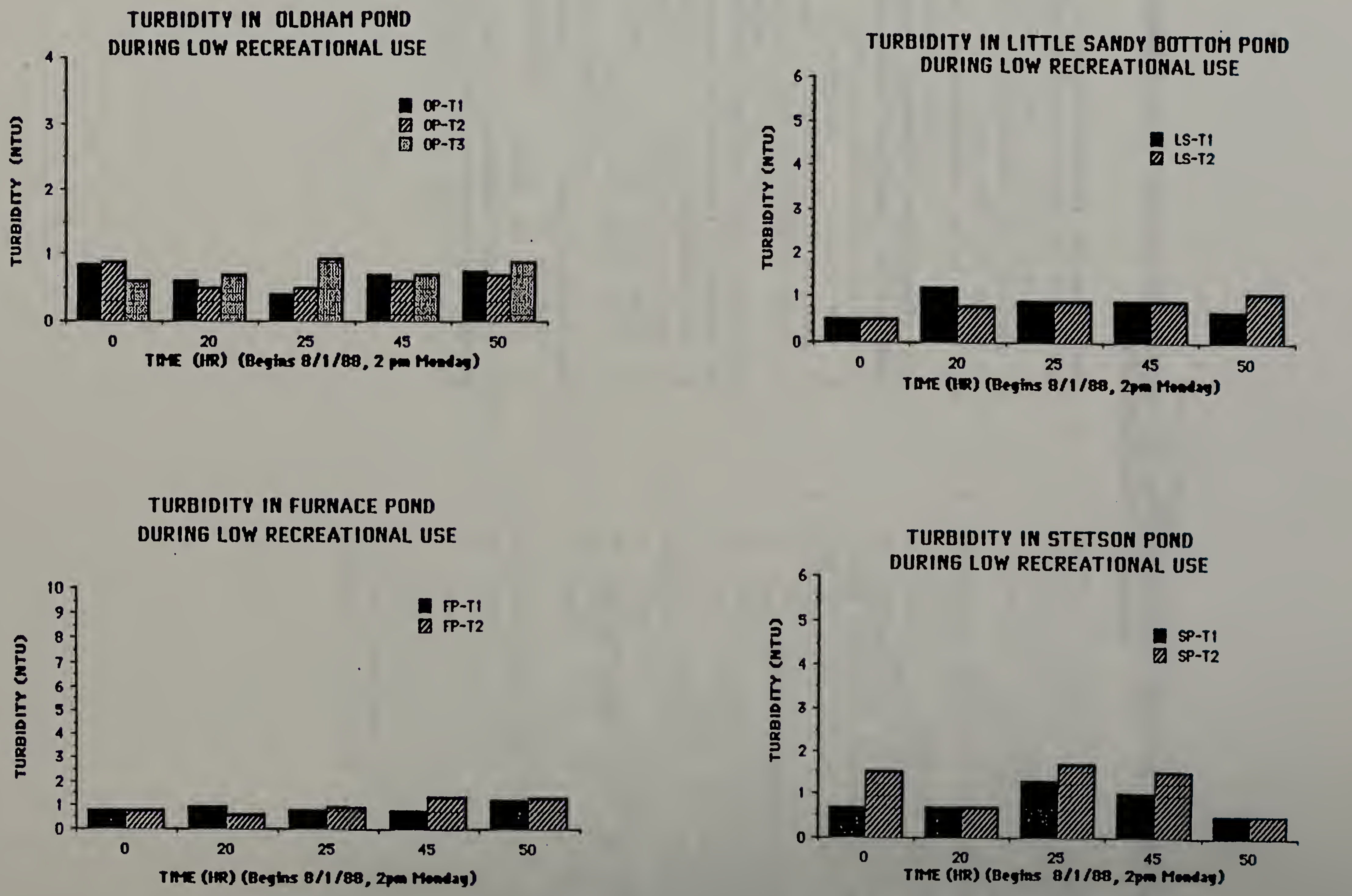
5. **Shallowness ratio**
   (area <5 ft deep/total area)
   a. Low (<0.10)
   b. Medium (0.10-0.25)
   c. High (0.25-0.50)
   d. Very high (>0.50)

6. **Shoreline development**
   (shoreline length/circumference of circle with lake area)
   a. Low (<1.5)
   b. Medium (1.5-3.0)
   c. High (>3.0)

7. **Littoral zone bottom coverage by rooted plants**
   a. Low (<25%)
   b. Medium (25-50%)
   c. High (50-75%)
   d. Very high (75-100%)

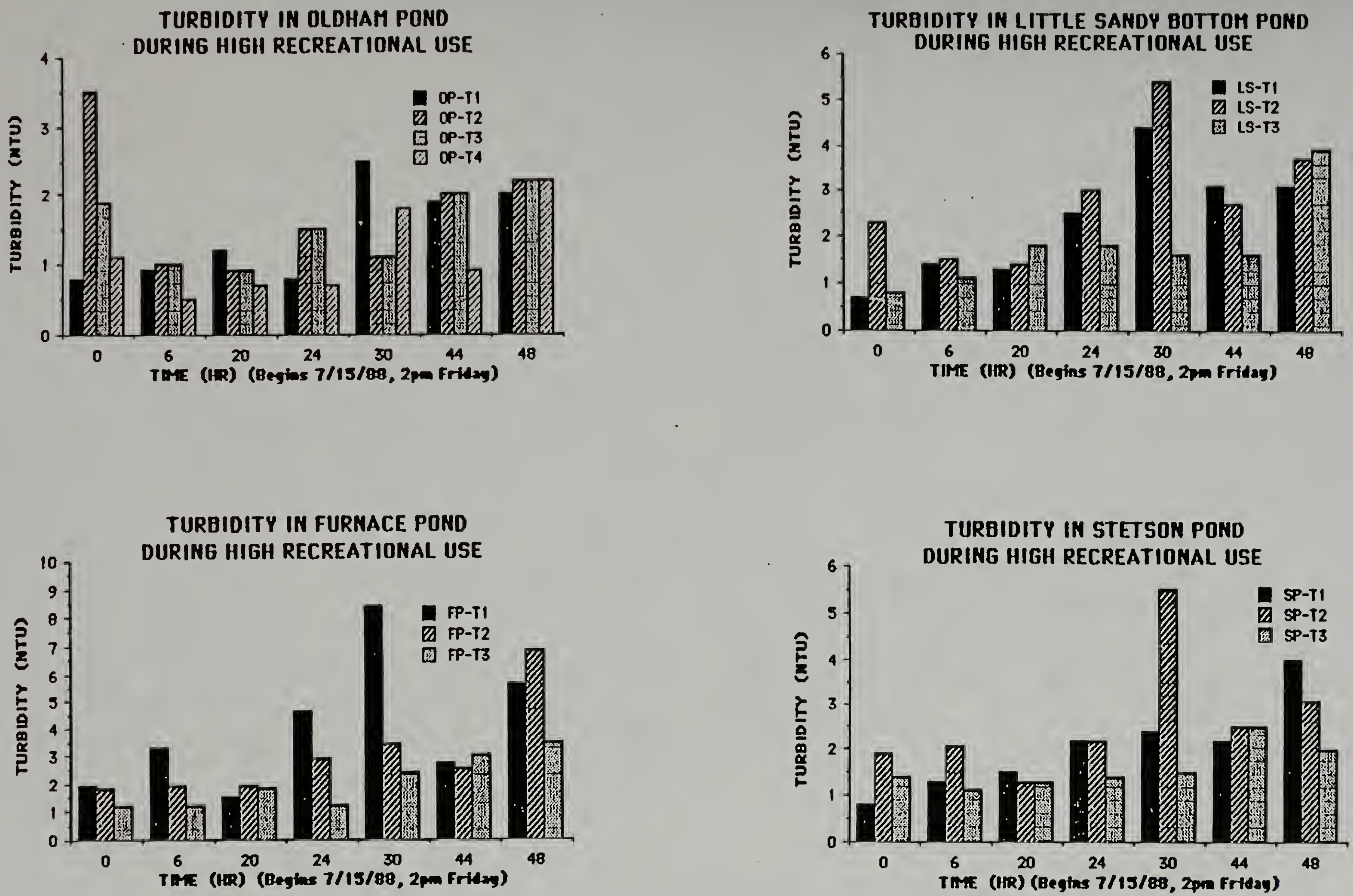
8. **Substrate type**
   a. Cobble
   b. Gravel or sand
   c. Silt or clay
   d. Organic muck

FIGURE 1. TURBIDITY IN FOUR PONDS DURING NEAR ABSENCE OF MOTORIZED WATERCRAFT



ALL STATIONS LOCATED ALONG SHORELINE AT WATER DEPTH OF THREE FEET

FIGURE 2. TURBIDITY IN FOUR PONDS DURING ELEVATED USE BY MOTORIZED WATERCRAFT



TURBIDITY IN OLDHAM POND DURING HIGH RECREATIONAL USE

TURBIDITY IN LITTLE SANDY BOTTOM POND DURING HIGH RECREATIONAL USE

TURBIDITY IN FURNACE POND DURING HIGH RECREATIONAL USE

TURBIDITY IN STETSON POND DURING HIGH RECREATIONAL USE

STATIONS OP-T4, FP-T3, LSBP-T3 AND SP-T3 ARE LOCATED CENTRALLY WITHIN EACH LAKE; ALL OTHER STATIONS ARE LOCATED ALONG SHORELINE AT A WATER DEPTH OF THREE FEET

APPENDIX

LONG POND

(Rutland)

General Information:

Actually, Long Pond is composed of three ponds, the 81 acre southern Pond is the largest and deepest, averaging 8.0 feet with a maximum of 25.0 feet. Aquatic vegetation is abundant around the shallow area just south of Rt. 122. A large paved boat ramp is located directly off the highway providing excellent boat access into the south (largest) pond. A spacious parking area is capable of accomodating in excess of 50 vehicles.

The middle basin sits between Rts. 122 and 122A. A culvert, impassable to boat traffic connects the middle pond to the southern pond. Aquatic weeds proliferate here as depth seldom exceeds a couple of feet. An informal access consisting of a dirt road leads to the waters edge about mid-way along the middle pond off the north-bound lane off Rt. 122.

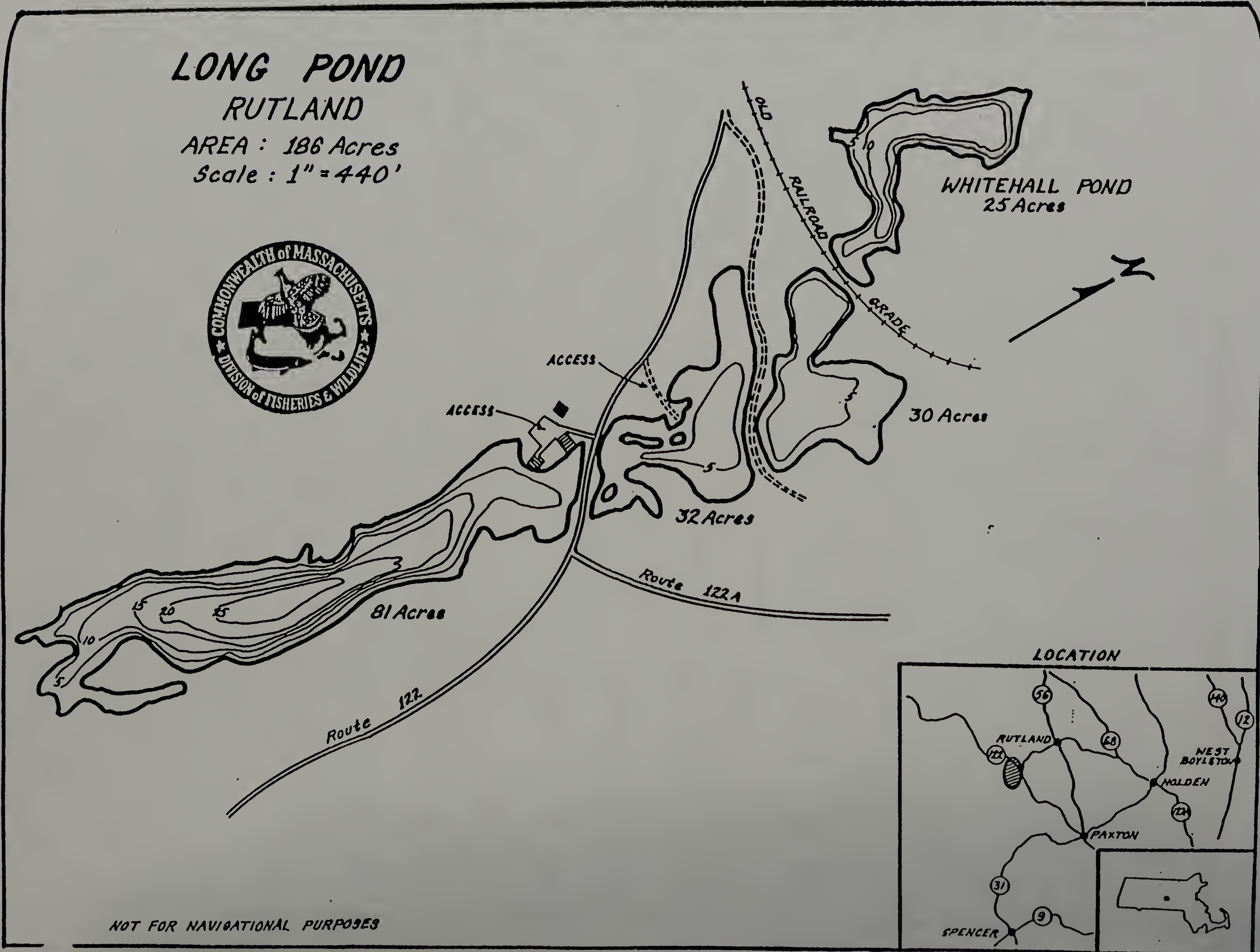
The north pond (30 acres) is similar in character to the middle pond, being shallow and quite weedy.

Fish Species Present:

The fish population was most recently sampled during the summer of 1979. Twelve species were present. The resident gamefish include largemouth bass and chain pickerel; and while yellow perch, white perch, black crappie, bluegill, pumpkinseed, rock bass, and brown bullheads composed the panfish fauna, white suckers and golden shiners are the only species of rough fishes present.

Fishing:

A good bet for largemouth bass and for those who are searching for bullheads of "eating size," try Long Pond.



LONG POND

RUTLAND

AREA : 186 Acres

Scale : 1" = 440'

NOT FOR NAVIGATIONAL PURPOSES

LABORATORY OUTLINE

1. Design a lake management program for Whitehall Pond (2:00-3:30 pm)

2. Group presentations and discussions of management programs (3:30-4:30 pm)

3. Discussion of the role of DEM's divisions in designing management programs and carrying out action plans. (4:30-5:00)

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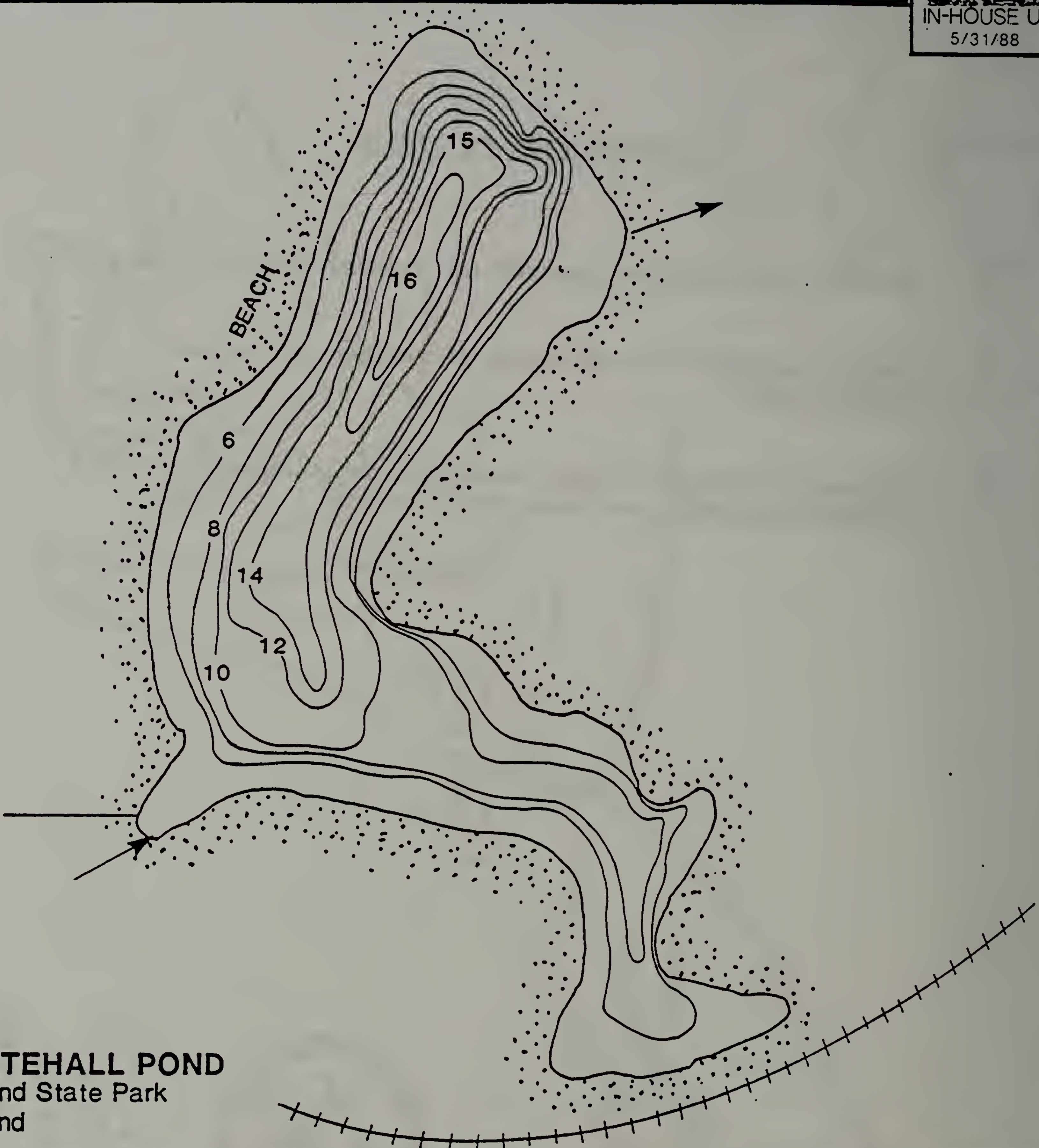

WHITEHALL POND
Rutland State Park
Rutland

Diagnostic Evaluation
21 Lakes & Ponds

MA Department of
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Division of Waterways

BATHYMETRY
WATER DEPTH (ft.) —5—

JASON M. CORTELL AND ASSOCIATES INC.

NOT TO SCALE

LABORATORY SESSION:
WHITEHALL POND MANAGEMENT PROGRAM

Task: Each team must develop a cost effective lake management program for Whitehall Pond.

When developing the management program, each team should determine:

1) how the lake and its watershed should be managed in the short-term and long-term
2) who at DEM should be responsible for the following:
   a. long-term pond and watershed management planning
   b. lake sampling and analysis
   c. in-lake and watershed management techniques
   d. permitting

DIAGNOSTIC EVALUATION

Whitehall Park allows several recreational uses of its pond and parkland. Recreational uses of Whitehall Pond include swimming in a designated swimming beach, fishing and ice-fishing, skating, and non-motorized or electrically motored boating. Recreational land uses include picnicking, field sports, snowmobiles, horseback riding, and trailbiking on the railroad bed immediately south of the pond. Problems of summer weed growth have been experienced by park managers. Approximately two years ago the park was harvested for weeds. No weed harvesting has occurred since.

Jason Cortell and Associates, Inc. conducted a diagnostic evaluation of Whitehall Pond in 1986 and 1987. Based upon this study, the following information was produced. For the purposes of this laboratory, assume that this information is correct and current (i.e. collected in 1989).

Bathymetry and Morphometry

The bathymetry of Whitehall Pond was measured with a recording fathometer. The bathymetry map for Whitehall Pond is enclosed. Whitehall Pond is a 25 acre pond which has an average depth of 10 feet, a maximum depth of 16 feet and a volume of 10.89 millions of cubic feet. In reality, Whitehall Pond is hydraulically connected to Long Pond, but for simplicity, assume that Whitehall Pond is NOT HYDRAULICALLY CONNECTED TO LONG POND.

Sediments

Lake and pond sediments were analyzed. Whitehall Pond contained 3 feet of mud in its shallow coves and sand along the shoreline and under the mud.

Water Quality

Water quality sampling and analysis were conducted on three occasions during the summer of 1986. For the purposes of this laboratory, assume that these samples were taken in 1989. A map showing the location of water quality sampling locations for Whitehall Pond is enclosed. Table 3-x presents water quality information and is enclosed.

Biological Components

A biological analysis of Whitehall Pond was completed. Whitehall Pond was found to be dominated by diatoms, rather than green algae, although green algae were still quite common. Tabellaria fenestrata, Fragilaria sp., Synedra sp., Asterionella formosa, and Cyclotella sp. were present. Green algae included Spirogyra sp., Staurastrum sp., Pediastrum sp., Cosmarium sp., and Coelastrum sp. Dinobryon sp., Mallamonas sp., and Ceratium were also present. Total cell densities averaged 491 cells per milliliter.

The water has a light amber coloration and visibility was very good at 5 feet. Shoreline aquatic vegetation were the dominant vegetative class. The dominants shoreline vegetation included common cattail, pickerelweed, and bulrush. Only moderate levels of milfoil were present.

Watershed Characteristics

Information gathered during Tuesday's watershed laboratory should be used to assess watershed impacts.

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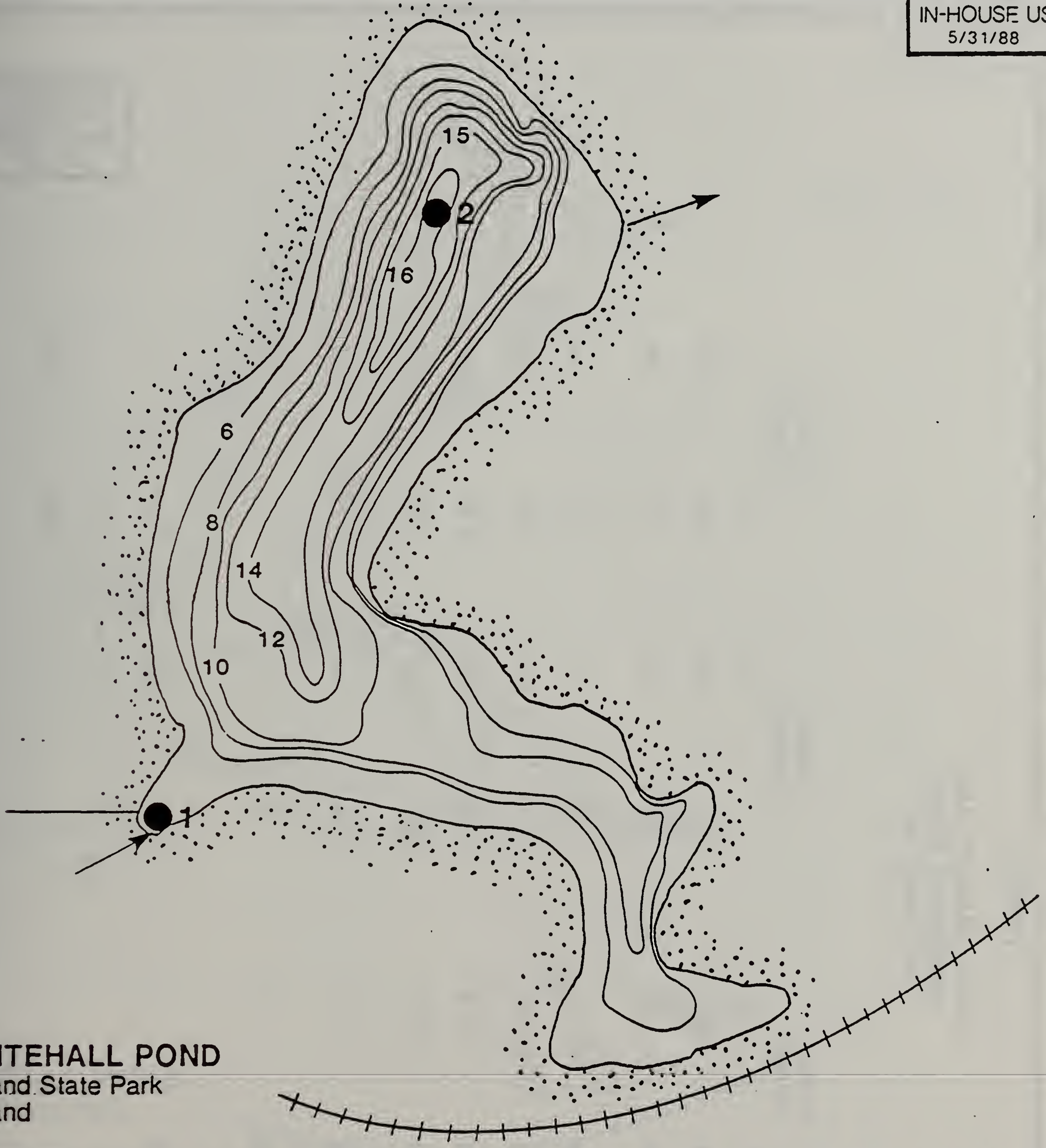

WHITEHALL POND
Rutland State Park
Rutland

Diagnostic Evaluation
21 Lakes & Ponds

MA Department of
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WATER QUALITY SAMPLING STATIONS

SAMPLING STATIONS 2 ●

JASON M. CORTELL AND ASSOCIATES INC.

NOT TO SCALE

3-9

Table 3-X

WATER QUALITY DATA
WHITEHALL POND
RUTLAND, MA

	Round 1 7/7/86		Round 2 8/12/86		Round 3 10/1/86	
	1	2	1	2	1	2
Ammonia(mg/l)	<0.1	<0.1	0.5	0.3	<0.1	0.25
Apparent Color (PCCU)	230	23	75	25	20	20
True Color (PCCU)	180	18	50	15	10	10
Nitrate (mg/l)	<0.02	<0.02	0.0	0.0	0.0	0.0
pH (mg/l)	5.0	6.8	6.2	6.3	6.50	6.43
Phosphate (mg/l) Total	0.03	<0.01	<0.2	<0.2	0.02	0.02
Total Alkalinity (mg/l)	1.5	6.4	34	34	17	17
Total Coliform Bacteria (colonies/100 ml)	<10	10	0	0	0	0
Fecal Coliform Bacteria (colonies/100 ml)	0	1	0	0	0	0
Turbidity (mg/l)	–	–	–	–	1.00	1.02

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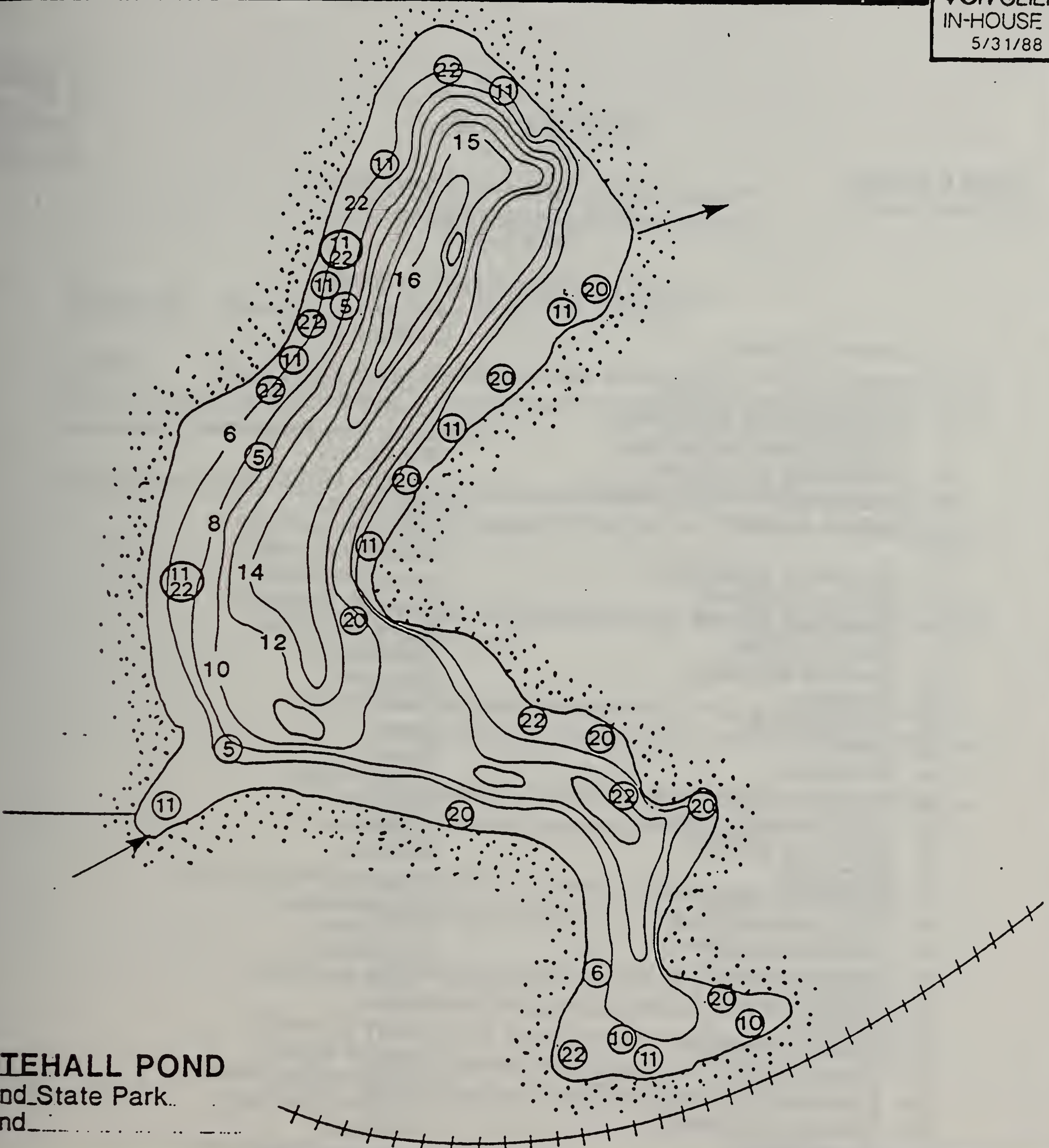

WHITEHALL POND
Rutland State Park
Rutland

Diagnostic Evaluation
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VEGETATION
SPECIES TYPE -⑬-

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3–15

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Table 3-XIV

AQUATIC VEGETATION SURVEY

	Scientific Name	Common Name
1.	*Potamogeton robbinsii*	Fernleaf Pondweed
2.	*Ceratophyllum demersum*	Coontail
3.	*Potamogeton Richardsonii*	Richardson Pondweed
4.	*Vallisneria americana*	Wild Celery
5.	*Myriophyllum heterophyllum*	Variable Milfoil
6.	*Nuphar advena*	Spatterdock
7.		Filamentous Algae
8.	*Polygonum amphibium*	Water Smartweed
9.	*Elodea canadensis*	American Elodea
10.	*Nymphaea odorata*	Fragrant Waterlily
11.	*Typha latifolia*	Common Cattail
12.	*Brasenia schreberi*	Watershield
13.	*Isoetes* sp	Quillwort
14.	*Utricularia* sp	Bladderwort
15.	Musci	Moss
16.	Graminea	Grass
17.	*Decodon verticillatus*	Water Willow
18.	*Cabomba caroliniana*	Fanwort
19.	*Sagittaria latifolia*	Arrowhead
20.	*Scirpus* sp	Bulrush
21.	*Potamogeton natans*	Floatingleaf Pondweed
22.	*Pontederia cordata*	Pickerelweed
23.	*Wolffia columbiana*	Watermeal
24.	*Lemna minor*	Duckweed
25.	*Callitriche verna*	Water Starwort
26.	*Nitella*	Nitella
27.	*Nymphea tuberosa*	White Waterlily
28.	*Najas flexilis*	Slender Naiad
29.	*Potamogeton diversifolius*	Snailseed Pondweed
30.	*Eleocharis acicularis*	Slender Spikerush
31.	*Eriocaulon* sp	Pipewort
32.	*Potomogeton amplifolius*	Largeleaf Pondweed

PRACTICUM:

THOMPSON'S POND ASSESSMENT AND MANAGEMENT PROGRAM

PURPOSE: Manage Thompsons Pond Watershed.

TASK: Each team must conduct a lake assessment of Thompsons Pond. Based upon this assessment, a management program must be developed and necessary permits must be identified.

ASSUMPTIONS:

a. Your organization has an annual lake assessment and management budget of $100,000 for Thompson Pond.

b. A USGS topographic map for the Thompsons Pond is provided.

c. Land around Thompsons Pond is zoned 1/2 acre residential, but there may be other pre-existing uses.

d. Each cabin at the 4-H Camp (DEM land) discharges 330 gallons of wastewater per day.

e. The DEM/4-H cafeteria discharges 75 gallons of wastewater per day.

f. All dwellings located off of DEM land and in the watershed and ground-water recharge area to Thompsons Pond consist of 3 bedroom single family homes which generate 330 gallons of wastewater per day.

EXISTING INFORMATION

Land and Water Uses

Thompsons Pond is a relatively shallow pond which possesses several coves. There is currently a considerable amount of residential development along the pond. Recreational uses of Thompsons Pond include swimming in a designated beach and along several residential shorefronts, motor boating, fishing, and skating. The DEM leases a portion of its land to the 4-H Clubs of America, which runs a summer camp for children during the months of May through October. The summer camp runs at capacity during these months.

Problems of summer weed growth and swimmer safety have been experienced by the 4-H camp in recent years. Weed growth has impeded swimming. In addition, boaters have been careless, and have come close to the 4-H swimming area and to boat fishermen.

A diagnostic evaluation was conducted for Thompsons Pond in 1986 and 1987 by Jason Cortell and Associates, Inc. Based upon this study the following information was gained:

Bathymetry and Morphometry

Figure 3-4 presents the shape and bathymetry of Thompsons Pond. Thompsons Pond has a drainage area of 3,456 acres and is 117 acres in size. The Pond has an average depth of 8 feet and a maximum depth of 20 feet. The volume of Thompsons Pond is 40.77 millions of cubic feet.

Sediments

Thompsons Pond contained up to 3 feet of mud at the northern end of the upper basin and eastern cove. Less than one foot was located in the lower basin. Sand and gravel was found under the mud.

Water Quality Analysis

Water quality sampling and analyses were conducted on three occasions during the summer of 1986. Sample locations for Thompsons Pond are shown in Figure 3-10. Water quality data for the Pond is presented in Table 3-XI.

Biological Analyses

Thompsons Pond was sampled for algae in its lower basin. The phytoplankton community was found to be co-dominated by diatoms and flagellated algae.

Thompson Pond contained aquatic vegetation predominantly in its lower basin. Aquatic vegetation in the upper basin was sparse and scattered and limited to the shoreline.

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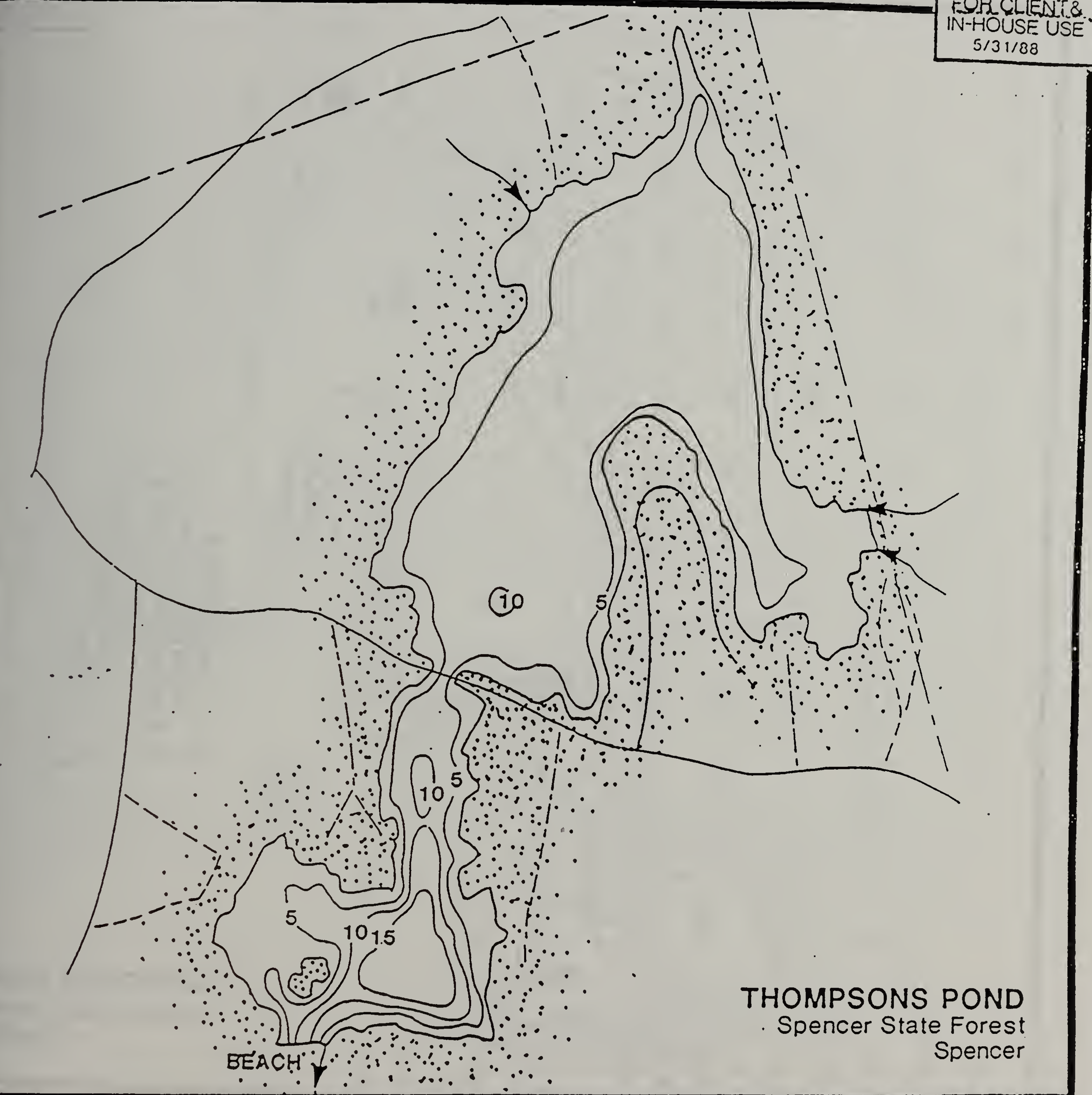

THOMPSONS POND
Spencer State Forest
Spencer

Diagnostic Evaluation
21 Lakes & Ponds

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BATHYMETRY
WATER DEPTH (ft.) — 5 —

JASON M. CORTELL AND ASSOCIATES INC.

NOT TO SCALE

3–4

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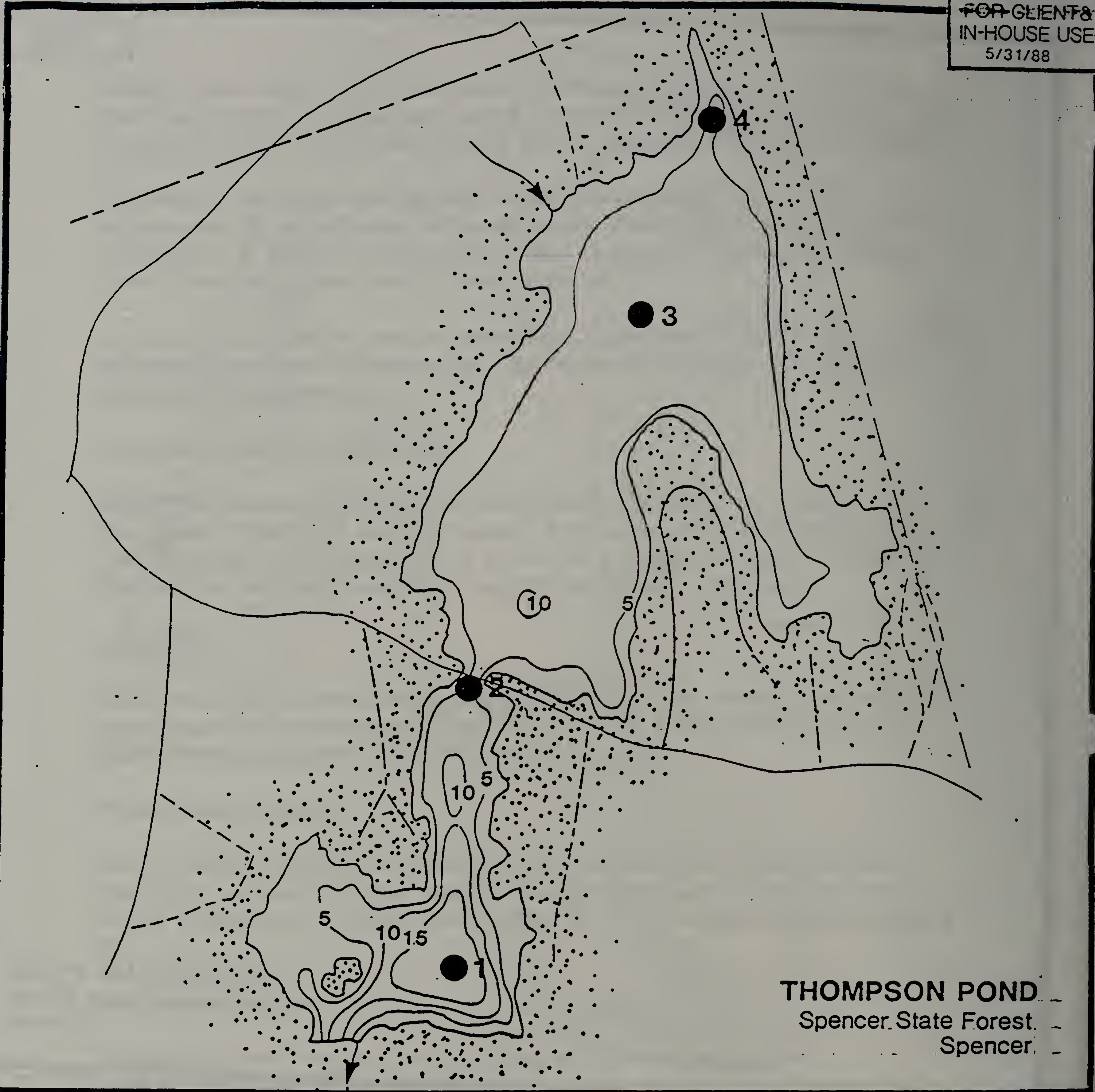

THOMPSON POND
Spencer State Forest
Spencer

Diagnostic Evaluation
21 Lakes & Ponds

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WATER QUALITY SAMPLING STATIONS
SAMPLING STATIONS 2●

JASON M. CORTELL AND ASSOCIATES INC.

NOT TO SCALE

3–10

Table 3-XI

WATER QUALITY DATA
THOMPSON POND
SPENCER, MA

	Round 1 7/8/86				Round 2 8/13/86				Round 3 10/1/86			
	1	2	3	4	1	2	3	4	1	2	3	4
Ammonia(mg/l)	.016	.012	<.01	.013	0.6	0.6	0.7	0.7	0.4	0.4	0.4	0.4
Apparent Color (PCCU)	75	80	86	86	75	100	100	125	70	70	80	80
True Color (PCCU)	70	70	70	80	50	75	50	100	40	40	60	60
Nitrate (mg/l)	<0.01	.040	.015	<0.01	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5
pH (mg/l)	6.7	6.6	6.6	6.7	5.6	5.8	5.9	6.0	5.1	5.9	5.9	6.1
Phosphate (mg/l) Total	<.01	<.01	<.01	<.01	<0.2	<0.2	<0.2	<0.2	0.01	0.02	0.02	0.01
Total Alkalinity (mg/l)	8.5	7.9	8.1	8.1	17	17	17	17	34	34	34	34
Total Coliform Bacteria (colonies/100 ml)	10	0	0	30	0	0	0	100	0	0	0	0
Fecal Coliform Bacteria (colonies/100 ml)	0	0	0	0	0	0	0	0	0	0	0	0
Turbidity (mg/l)	–	–	–	–	–	–	–	–	0.9	0.9	1.0	1.2

ANNOTATED BIBLIOGRAPHY OF KEY SOURCES

Cooke, D.G., E.B. Welch, S.A. Peterson, and P. Newroth. 1986. Lake and Reservoir Restoration. Butterworth Publishers. New York, NY. - A recent, fairly complete manual of important methods of restoring and improving lakes, ponds and impoundments. Each section is well-documented with case histories and useful information regarding the feasibility of the method to various lake problems. Aimed at a professional or managerial audience, with better treatment of engineering considerations for technique implementation. (May be currently out of print.)

Fassett, N.C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI. - Still the most useful single comprehensive guide to the aquatic and semi-aquatic plants. A revised edition is nearing completion (1991) and should include distribution information for New England (one of the co-authors is Dr. Hellquist, a local expert).

Freeze, A.R. and J.A. Cherry. 1979. Groundwater Prentice Hall, Inc., New Jersey. - An introductory text about ground water which describes the physical and chemical properties of ground water, reviews ground water geology and describes causes of ground water contamination.

Goldman, C.R. and A.J. Horne. 1983. Limnology. McGraw-Hill Publishing Company. New York, NY. - An extremely readable introductory text of limnology and related water resources. Provides an interesting overview of the biology of lakes and ponds, with more emphasis on systems outside of northern temperate zones (tropics, arctic) than most textbooks.

Hutchinson, G.E. Treatise on Limnology. Vol. I. Geography, Physics, and Chemistry (1957); Vol. II. Introduction to Lake Biology and the Limnoplankton (1967); and Vol. III. Limnological Botany (1975). John Wiley and Sons, Inc. New York, NY. - The "bible" of limnology in three parts. An exhaustively researched, scholarly work that is still valuable as a reference source, while becoming somewhat dated with the advances in the field. A necessary possession in the library of any serious lake scientist.

Lind, O.T. 1979. Handbook of Common Methods of Limnology. C.V. Mosby Co. St. Louis, MO. - An inexpensive and concise compendium of the most commonly used techniques and equipment for lake sampling and laboratory analysis. Physically compact, this is the type of book that can easily accompany workers in the field (slip it in a jacket pocket!).

Reckhow, K.H., M.N. Beaulac and J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty. A manual and compilation of export coefficients. Office of Water Regulations and Standards. EPA 440/5-80-011. Washington, DC. - A highly technical publication used largely for derivation of nutrient budgets for lakes. While the mathematical models are largely of interest only to workers in the field, it is still the best documented source of export coefficients, which are used in the formulation of watershed loading estimates.

Schueler, T.R. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMP's. Metropolitan Washington Council of Governments. - This manual provides guidance to engineers and planners on how to design a watershed management program aimed at removing pollutants typically associated with stormwater runoff.

United States Army Corps of Engineers. 1988. Technical Report A-88-9, Aquatic Plant Identification and Herbicide Use Guide. Vol. I: Aquatic Herbicides and Application Equipment. - A good compendium of the research dealing with the impacts and proper application of herbicides.

United States Department of Agriculture. Soil Conservation Service. Erosion and sediment control in site development. Massachusetts Conservation Guide. Vol. I and II. Amherst, MA. - This guidebook describes erosion and sediment problems that arise in site development and explains how to minimize them.

United States Department of Agriculture. Soil Conservation Service. 1989. Standard forest land erosion control (acre). Field Office Technical Guide. Section IV. Amherst, MA. - Describes typical measures available to control erosion and sedimentation resulting from forestry activities.

United States Environmental Protection Agency. 1990. The Lake and Restoration Guidance Manual (2nd edition) and Monitoring Lake and Reservoir Restoration (Technical Supplement). Office of Water Regulations and Standards. EPA 440/4-90-006. Washington, DC. - An updated and improved restoration manual aimed at the educated layperson. A very accessible and useful handbook for guiding a lake association through the data-gathering and decision-making necessary in any lake management program. The manual is organized around the types of lake problems to be managed and each chapter is well illustrated with relevant case histories. The appendices contain a wealth of useful information.

Witten, J.D. 1986. The Falmouth Nutrient Loading Bylaw: A Regulatory Approach Toward Minimizing the Effect of Nutrients Upon Fresh and Coastal Water Systems. North American Lake Management Society, Washington, DC. - Presents a mechanism for evaluating the impact of development upon water quality. This approach has since been adopted by communities throughout Massachusetts.